Early Adopters of Geospatial Technologies for Teaching Geography in Australian Secondary Schools

by

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Declaration of Originality

This thesis contains no material which has been accepted for a degree or diploma by the University or any other institution, except by way of background information and duly acknowledged in the thesis, and to the best of my knowledge and belief it contains no material previously published or written by another person except where due acknowledgement is made in the text or the thesis, nor does the thesis contain any material that infringes copyright.

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Statement Regarding Published Works and Co-authorship

Some of the material in Chapter 8 has been published in a co-authored paper by Bianca Coleman, Dr Peter Brett and Kim Beasy. The material was jointly conceptualised, the data analysis and a first draft were done by Bianca Coleman, and Dr Peter Brett and Kim Beasy contributed to the final draft.

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Authority of Access

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Statement of Ethical Conduct

The research associated with this thesis abides by the international and Australian codes on human and animal experimentation, the guidelines by the Australian Government's Office of the Gene Technology Regulator, and the rulings of the Safety, Ethics and Institutional Biosafety Committees of the University.

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Abstract

This research examined the use of geospatial technologies in secondary geography education in Australian secondary schools (students aged 13-18 years). Geospatial technologies (GST) are hardware and software used to collect and analyse geospatial (geographical) data and include geographical information systems (GIS), Global Positioning Systems (GPS) and remote sensing. The use of these technologies for geography education has been incorporated into the recently developed *Australian Curriculum: Geography* (Years 7-10) curriculum framework. Despite their inclusion in the curriculum, however, existing research continues to report low levels of GST adoption by teachers.

This research investigated the experiences of ‘early adopters’ of geospatial technologies teaching in Australian schools. As teachers who have adopted the technologies prior to most of their peers, early adopters are well placed to identify challenges and opportunities that stem from the use of GST in geography teaching. Accordingly, this study examined the characteristics of early adopters of GST (such as their knowledge, confidence and experience for teaching with GST), the influence of context on their use of GST, and the ways in which they employ GST to enhance their geography teaching. Furthermore, this study identified the mechanisms through which these early adopters support and encourage their peers to also adopt the technology within their own practices.

A quantitatively-driven mixed-methods research design was employed to collect and analyse data. An initial survey collected data from 53 Australian secondary geography teachers about their technological, pedagogical and content knowledge for teaching with GST. Follow-up semi-structured interviews with eight

of these early adopters were also conducted and ‘teaching artefacts’ (such as lesson and unit plans, worksheets and de-identified student work samples) were collected.

Statistical analyses (*t*-tests and descriptive statistics) and thematic interview analysis revealed that early adopters are highly knowledgeable in their geographical knowledge, their capacity to teach geography and their understanding of how geospatial technologies can be embedded within geography teaching. These teachers identified a range of micro-, meso- and macro-level context conditions that influence (both constrain and enable) their GST teaching practices. Analysis of the teachers’ lesson plans and student work samples revealed how the skilful and purposeful application of GST in teaching can engage students in higher-order thinking and develop their geography knowledge. Finally, this study also concluded that early adopters encourage the widespread diffusion of geospatial technologies amongst other geography teachers by experimenting with and sharing resources, providing for professional learning opportunities and exercising curriculum leadership in schools.

Dedication

For Margaret and for Ruth.

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List of Acronyms and Abbreviations

Acronyms and abbreviations used in this thesis include:

ACARA: Australian Curriculum, Assessment and Reporting Authority

BYOD/T: Bring Your Own Device/Technology

CK: Content Knowledge

DER: Digital Education Revolution

DOI: Diffusion of Innovations theory

GIS: Geographic Information Systems

GLONASS: Globalnaya Navigatsionnaya Sputnikovaya Sistema (Russian GPS/GNSS system)

GPNSS: Global Navigation Satellite Systems

GPS: Global Positioning System (American system, also termed Navstar GPS)

GST: Geospatial technologies

GTA: Geography Teachers Association

GTANSW: Geography Teachers Association of New South Wales

GTAV: Geography Teachers Association of Victoria

ITE: Initial Teacher Education

NAPLAN: National Assessment Program – Literacy and Numeracy

NSW: New South Wales

PCK: Pedagogical Content Knowledge

PD: Professional Development

PK: Pedagogical Knowledge

PL: Professional Learning

TCK: Technological Content Knowledge

TK: Technology Knowledge

TPACK: Technological, Pedagogical and Content Knowledge

TPK: Technological Pedagogical Knowledge

QZSS: Quasi-Zenith Satellite System (Japan)

Chapter 1

Introduction

1.1 Introduction

This study sought to examine the ‘problem’ of geospatial technologies and their inclusion as a pedagogical tool for geography teaching within the recently developed national geography curriculum. Geospatial technologies are hardware and software that can be used to collect, visualise, manipulate, and analyse geospatial (geographical) data. Examples of geospatial technologies include: Global Positioning Systems (GPS), geographical information systems (GIS) and remote sensing technologies (RS) (Fargher, 2018; Muñiz Solari, Demirci & van der Schee, 2015). The use of GST for secondary geography education is mandated within the national curriculum, *Australian Curriculum: Geography,* which has been implemented in stages across Australian schools since 2014. Despite this mandate, previous research indicates that the widespread adoption of geospatial technologies in schools has yet to be realised (Baker & Langran, 2016; Schubert & Uphues, 2009). The low adoption rate of GST in schools presents a considerable challenge to the new curriculum mandate. According to the literature, GST are currently the domain of more innovative ‘early adopters’ – teachers who have taken up the challenge of teaching with GST before most of their colleagues – not a widely adopted pedagogical practice.

In response to the problematic presence of GST in *Australian Curriculum: Geography*, this study examined the experiences of early adopters of GST teaching geography in Australian secondary schools. Specifically, this research examined early adopters' knowledge and confidence for teaching with GST, how early adopters use GST for teaching *Australian Curriculum: Geography* and the influence of context on the teaching practices. Early adopters stand to play an important role in driving the adoption of GST amongst their colleagues by sharing their experiences, opinions and knowledge about how the technology can be used for geography teaching (Rogers, 2003).

1.2 Research Context

Geographical education is undergoing a period of renaissance in Australia. With the design and implementation of *Australian Curriculum: Geography* the place of geography in school education has been firmly cemented. Historically, however, geography has held an uneasy position in Australian school curricula. While mathematics and English have long been considered essential learnings for all Australian school students, the teaching of geography in Australian schools has been subject to a variety of social and political forces that have "marginalised" (Hutchinson, 2006, p. 195) the subject in schools. The almost universal adoption of interdisciplinary social studies education from the 1970s and 1980s (often called Studies of Society and Environment, Human Society and Its Environment or Society and History in Australian schools) has been criticised by advocates of geography education for diminishing the place of geography in favour of history and civics and citizenship education. These educationalists suggest that the flow-on effects of social studies education have included declining student retention in post-compulsory geography subjects, a teaching workforce with limited expertise in geography and fewer young people pursing some geography-related careers (Australian Geography Teachers Association, 2007; Freeman, 2006; Hutchinson, 2006; Robertson & Doyle, 2006).

The introduction of a national curriculum in geography, and its subsequent implementation in schools, represents a reinvigoration of geography education in Australia. While subsequent revisions of the *Australian Curriculum* have returned to an integrated subject framework for geography and history in primary school education (F-6/7 *Humanities and Social Sciences*), geography retains its own distinct subject framework in the secondary school. With this curriculum mandate, schools and teachers have an opportunity to renew geographical education through the purposeful and effective teaching of geography knowledge and skills.

1.2.1 Geospatial Technologies

In addition to providing a clear mandate for renewing geographical education in schools, *Australian Curriculum: Geography* also highlights and articulates the centrality of technology, particularly GST, in teaching, learning and 'doing' geography in the twenty-first century. As signposted by the *Australian Curriculum: Geography*, the most commonly used geospatial technologies in education include Global Positioning System (GPS), Google Earth, geographic information systems (GIS) and satellite images (ACARA, 2016). While traditionally the domain of professional geographers, increased reliance on these technologies over the past two decades for daily activities (such as using GPS for directions while driving or calculating and tracking running distances) has opened up opportunities for 'lay-people' or non-geographers to engage with and make use of these technologies.

Indeed, GST have become ubiquitous in twenty-first century society driven by demand for, and widespread use of, free or low-cost GST applications. Perhaps most significantly, the development of Google's mapping platforms (Google Maps, Google Earth, Google MyMaps) as free downloadable or web-based software now allows anyone with an internet-capable device to engage with geospatial information. This software, coupled with the popularity of 'smartphones' and other portable devices (such as laptops, tablets and iPads), has led to unprecedented levels of access to geospatial information amongst non-geographers. The pervasiveness of GST has led many in education to argue that GST should be adopted in schools to promote teaching and learning (Alibrandi, 1998; McInerney, 2002).

Many geography education stakeholders have long championed the use of GST for school geography education. Freeman (1991), for example, proposed the development of a GIS for use in English schools. In 1993, researchers at the American National Centre for Geographic Information and Analysis examined the prospects of GIS in American secondary schools. Researchers have found evidence to support the contention that GST has the capacity to enable students' development of critical thinking skills and knowledge of geography concepts and topics (Bodzin & Fu, 2014; Demirci, Karaburun & Kilar, 2013). The inclusion of the geospatial technologies within *Australian Curriculum: Geography* represents an acknowledgement by Australian curriculum-makers of the relevance and utility of GST for improving and supporting student learning in secondary geography.

Despite the educational benefits reported to stem from the use of GST in the classroom, previous research conducted both in Australia and internationally indicates that the uptake of the geospatial technologies in school classrooms has been limited. Although a more recent analysis of GST use in schools is warranted, Kerski (2000) found only two percent of American high school teachers reported using GIS in the classroom. More recent commentary on GST education has anecdotally supported Kerski's findings (Baker & Langran, 2016; Schubert & Uphues, 2009; Wheeler et al., 2010).

1.3 Research Problem

Given the limited uptake of GST amongst teachers, the inclusion of the technology within *Australian Curriculum: Geography* presents a problem. If few teachers are reported to be using the technology for teaching, what are the implications of the inclusion of GST for geography education in Australia? Can *Australian Curriculum: Geography* act as a catalyst for the widespread adoption of GST in geography teaching? For which topics and learning tasks should teachers adopt geospatial technologies when teaching *Australian Curriculum: Geography*? Are geography teachers sufficiently prepared to take up the challenge of teaching with GST? The inclusion of geospatial technologies within *Australian Curriculum: Geography* before widespread adoption of the technologies amongst teachers presents a variety of issues for schools, teachers, curriculum-makers and researchers to address.

This research investigated some of the issues surrounding the use of geospatial technologies in teaching by examining the experiences of early adopters of the technology who are teaching geography in Australian secondary schools. Specifically, this research identified these early adopters, examined their knowledge and confidence for teaching with GST, described how early adopters use GST in their teaching and analysed the extent to which the contexts in which the teachers work influences their teaching of *Australian Curriculum: Geography* with GST. Additionally, this research also considered the role of early adopters in encouraging and supporting their colleagues to use GST and their capacity to promote the widespread adoption of the technologies amongst the geography teaching workforce.

1.4 Research Purpose and Significance

The purpose and significance of this research is four-fold. First, the implementation of *Australian Curriculum: Geography* and the inclusion of geospatial technologies within the curriculum presents a number of challenges related to the preparedness of teachers to use GST in teaching. This research sought to investigate the experiences of early adopters of geospatial technologies in their geography teaching. The knowledge and confidence of early adopters for using GST was examined with the intention of identifying the current level of knowledge about GST implementation held by Australian secondary school geography teachers. By examining the practices of early adopters, and their perceptions of their knowledge and confidence for teaching with GST, the findings of this research go towards identifying the professional learning needs of teachers in schools (including those who have not yet adopted the technology) and pre-service teachers undertaking initial teacher education for teaching geography with GST.

Second, the inclusion of geospatial technologies in *Australian Curriculum: Geography,* before widespread adoption of the technologies in schools, presents an interesting dilemma for teachers, schools and policy makers. Many teachers who are new to geography teaching or who are non-geography specialists (e.g. previous teachers of social studies-focused education) may be uncertain about how GST can be used to teach *Australian Curriculum: Geography*. This research presents some examples of how early adopters use GST in the classroom. These examples stand to be useful demonstrations for teachers and schools for how GST can be used to teach geography and could provide non-adopters with the curriculum materials they need to implement the technologies in their own classrooms.

Third, this research investigated the influence of context on early adopters' practice of teaching with GST. While mandated within *Australian Curriculum: Geography*, previous studies have identified a range of barriers to the adoption of GST for teaching. Within the Australian school context, Wheeler, Gordon-Brown, Peterson and Ward (2010) and Kinniburgh (2008) provided analyses of the barriers to geospatial technology adoption in schools. In their study of GIS use in Victorian schools, Wheeler et al. (2010) found poor teacher knowledge of GIS, limited access to computers in schools, and the high cost of GST software were major barriers to the successful adoption of GIS in Victoria. While their study provided a comprehensive review of the barriers to GIS in schools in 2010, there have been significant improvements in technology provision in schools (such as Labor's 2008 Digital Education Revolution) and the increased accessibility of free GST applications for mobile devices. Thus, it is both pertinent and necessary to re-evaluate barriers to GST adoption in Australian schools and to also identify potential enabling context conditions that could support teachers in their use of the technology. This study's focus on early adopters (i.e. those teachers who make use of these technologies despite the identified barriers) provides critical insights into why other teachers may be reluctant to use them in the classroom and what context conditions may need to be addressed before these teachers come to adopt GST.

Finally, this research also makes a contribution to the theoretical literature about teachers' knowledge for teaching with technology and the processes whereby teachers adopt innovative practices in their teaching. To that effect, this research utilised the Technological, Pedagogical and Content Knowledge (TPACK) framework developed by Mishra and Koehler (2009) and the Diffusion of Innovations theory advanced by Rogers (2003) as the theoretical frameworks for interpreting findings. Further adaptions to the TPACK framework devised by Porras-Hernádez and Salinas-Amescua (2013) were also used to explore the importance of context in understanding and interpreting teacher knowledge for teaching with technology. Although there is extensive literature describing the TPACK framework, there has been little research attention paid to the role of context (particularly macro-level context conditions) in understanding teacher knowledge for teaching with technology (Rosenberg & Koehler, 2015). This study was designed to address this research gap.

1.5 Research Questions

To facilitate the study of early adopters of geospatial technologies, four research questions (RQs) were developed. These research questions were informed by an extensive review of the existing literature on the use of GST in geography teaching in Australia and internationally. In Chapter Two, after a review of the literature, the research questions are justified with reference to the 'gaps' in the existing literature.

RQ1. What are the characteristics of early adopters of geospatial technologies in geography teaching in Australian secondary schools?

RQ2. How do context barriers and enablers influence early adopters' use of geospatial technologies in their geography teaching?

RQ3. How do early adopters utilise geospatial technologies to enhance their geography teaching?

RQ4. In what ways do early adopters promote the diffusion of geospatial technologies amongst other geography teachers?

1.6 Research Approach

A sequential explanatory mixed-methods research design, as described by Plano Clark and Creswell (2008), was adopted in this study to collect and analyse research data. Quantitative data were first collected and analysed before follow-up qualitative data were collected and analysed. Justification for this research design is provided in Chapter Five.

To examine the knowledge and confidence of early adopters for teaching geography with GST, a well-validated TPACK survey instrument (Schmidt et al., 2009) was adapted to reflect the research focus on geospatial technologies for geography education. The survey was distributed to early adopters of GST teaching in Australian secondary schools and their responses were statistically analysed using IBM Statistical Package for the Social Sciences (SPSS v. 22).

To identify how early adopters are using GST in their teaching and to highlight the influence of context on teachers' practice, semi-structured interviews with eight early adopters were conducted. Thematic analysis, following the guidelines advocated by Braun and Clarke (2007), preceded data collection. This analysis identified and explained the influence of context on GST-enhanced geography teaching and the role of the early adopter in the diffusion of GST in Australian geography classrooms.

1.6.1 Diffusion of Innovations Theory

In addition to the technological, pedagogical and content knowledge (TPACK) framework, Rogers' (2003) Diffusion of Innovations theory (DOI) was employed in this study to investigate how early adopters of GST promote the spread of the technologies amongst their teaching colleagues. In describing those individuals who adopt an innovation prior to the majority of their peers, Rogers argued that early adopters "put their stamp of approval on a new idea by adopting it" (p. 283). DOI theory posits that early adopters are instrumental in encouraging and supporting others to take up an innovation by demonstrating the utility and purposes of the innovation to others in their professional and social networks.

1.7 Key Concepts and Terminology

Several concepts and terms are used in this study to describe the research focus and research sample. These terms are explained in this section.

1.7.1 Early Adopters

This study examined the teaching practices of early adopters of geospatial technologies teaching in Australian secondary school geography classrooms. The term 'early adopter' is drawn from the seminal work of Rogers (2003), first published in 1962, which examined the diffusion (or spread) of agricultural innovations in rural Iowa. In this work, Rogers described how innovations spread across a social group. Rogers posited that the spread of an innovation happens over time and across five separate sub-groups within a social group: the 'Innovators', 'Early adopters', 'Early majority', 'Late majority' and 'Laggards' (2003, pp. 247-251). Rogers argued that when an innovation is introduced, it will first be taken up and trialled by a group of less-risk averse ‘innovators’ within the social group. Representing just 2.5% of individuals within the group (p. 247), innovators have the resources and resilience to trial an innovation and sustain potential losses associated with its failure. Innovators are critical in providing an indication of an innovation’s worth to the next group of individuals that will take up the innovation: the early adopters.

Early adopters are the population studied within this thesis. While the Rogers’ innovators are the first to make use of an innovation, it is the early adopters who are most critical to the wide-spread diffusion of that innovation (Chau & Hai, 1998; Frattini, Bianchi, De Massis & Sikimic, 2003). Early adopters, which Rogers speculated to be the next 13.5% of individuals to adopt an innovation (p. 247), have a specific role in communicating to other members within their social group about the value and benefits to be derived from adopting an innovation. Early adopters communicate how easy or difficult it is to adopt the innovation and they act as role models for those members of the group who are more hesitant to take risks. Rogers argued that early adopters are “not too far ahead of the average individual in innovativeness” (2003, p. 249) and, therefore, other members of the social group place considerable trust in the early adopters to make “judicious innovation decisions” (p. 249) on behalf of the rest of the group. Early adopters, therefore, act as “opinion leaders” (p. 27), demonstrating to others in the group that an innovation can be relied upon to meet their needs. It is the early adopters who encourage their peers to make the economic or social investment in an innovation. In this way, early adopters help to inform the decisions of the next category of adopters to take up an innovation: the early majority (Rogers, 2003). Further explanation and discussion of the term ‘early adopter’, the characteristics of early adopters and Rogers’ *Diffusion of Innovations* theory can be found in Chapter Three, Section 3.3 (pp. 88-97).

Within this thesis, Rogers' (2003) *Diffusion of Innovations* theory is used to understand and theorise about the experiences of those teachers who currently make use of geospatial technologies within their geography teaching. While there is a distinct paucity of studies examining the experiences of Australian geography teachers in adopting GST for teaching, there are signs of innovators first beginning to trial GST in Australian geography classrooms from 2006 onward (see, for example, Kidman & Palmer, 2006; Kinniburgh, 2008; Wheeler et al., 2010). Although there has been limited research attention paid to this phenomenon, international research continues to suggest that GST is an under-utilised tool for teaching (Baker & Langran, 2016; Goldstein, 2010; Jo & Bednarz, 2014). At the commencement of this research in 2015, *Australian Curriculum: Geography* had only been published in the previous year. Therefore, as GST had only just been introduced within the curriculum as a required pedagogical tool for geography teaching, it was decided that the teachers who participated in this research should be classified as 'early adopters.'

While the purpose of this study was to understand the practices of those teachers who use already use GST in their geography teaching (that is, the early adopters), it is important to note that in studying this population of teachers, the experiences of those teachers that have yet-to-adopt GST have not been included in this work. This was a purposeful choice in the design of this study. This study was not intended to be a comparative study between early adopters and non-adopters. Rather, the experiences of early adopters were explored as a way of emphasising the challenges faced by many teachers and to provide some possible explanations as to why not all geography teachers are adopting these practices.

1.7.2 Geospatial Technology

Geospatial technology is an umbrella term used to categorise a range of digital technologies that can be used in geographic inquiry and analysis. Geospatial technologies allow geographical and spatial data to be collected, stored, manipulated and evaluated for the purpose of analysing a geographical problem and/or determining a course of action (Gold, 2006). As professional tools, GST have a wide range of applications in industries such as forestry, construction, urban planning, mining and transportation. Geospatial technologies used in industry that can be adapted for educational purposes in line with the *Australian Curriculum* requirements include Remote Sensing, Global Positioning Systems (GPS) and Geographic Information Systems (GIS). A brief explanation of each technology is provided here:

Remote sensing. Remote sensing is the science of detecting and mapping scenes or phenomena using sensors that detect energy reflected or transmitted by those scenes or phenomena (National Oceanic and Atmospheric Association, 2014). The sensors are often mounted in aircraft or satellites. Common examples are digital cameras mounted in aircraft, or multi-spectral scanners that extend across and beyond the visible spectrum mounted in satellites.

Global Positioning System (GPS)/Global Navigation Satellite System (GNSS). GPS/GNSS is a satellite navigation system that can provide accurate location data that can be visualised by any compatible device. Thirty-one space-based satellites, maintained by the U.S. Department of Defence, are capable of triangulating the location and time relevant to the GPS device. GPS requires an unobstructed view of at least four satellites to accurately determine location (National Coordination Office for Space-Based Positioning, Navigation and Timing, 2015). In recent times, other nations have developed their own satellite systems, such as Japan's Quasi-Zenith Satellite System (QZSS) and Russia's GLONASS.

Geographic information systems. A geographic information system (GIS) is a software program used to map and analyse spatial data. GIS allows for the visualisation of geospatial data and is a platform for analysing relationships, trends and patterns of distribution within and between geographical phenomenon (Esri, 2014). Esri's Arc-series of programs (ArcGIS, ArcView, ArcMaps) represent the leading commercially available GIS software, while QGIS is a widely used open-source alternative.

Geospatial technologies, when utilised by teachers in sophisticated and effective ways, can lead students to develop higher-order geography thinking skills and enable critical and creative ways for students to demonstrate their geography learning (Demirci, Karaburun & Kilar, 2013; Xian and Liu, 2017). Teachers' practices of utilising the following GST applications, software and hardware in the classroom are examined in this research:

Google Earth. Google's web-based program Google Earth provides users with access to a 3D representation of the Earth's surface – a 'virtual globe' that can be moved and manipulated by the user. Google Earth allows for the visualisation of satellite imagery, aerial photography and ocean bathymetry (ocean depth measurement data) within a single web-browser. In a classroom setting, Google Earth provides opportunities for students to visualise the Earth's surface and identify spatial variations in the surface, examine the physical characteristics of space, compare places at local, national, regional and global scales, and import layers of geospatial information that can be superimposed over a base-map. Research studies examining the use of Google Earth in the classroom have found the functions of Google Earth can help to foster students' spatial thinking skills (Patterson, 2007; Schultz, Kerski & Patterson, 2008) and ability to identify geographical features (Demirci, Karaburun & Kilar, 2013).

Google Maps. The Google Maps web-based platform provides similar affordances for teachers looking to foster students' geographical thinking skills using GST. In addition to allowing the visualisation of the Earth's surface via embedded satellite imagery, Google Maps focuses on providing navigational data (e.g. street addresses, directions, transit time information) and location data for public services (e.g. restaurants, medical facilities, recreation spaces). These features enable teachers and their students to examine geographical phenomenon at different scales and afford opportunities for students to investigate key geographical concepts (such as scale, distance, location, place and space) using Google Maps' measurement tools, direction calculator, and embedded map layers (road and satellite maps). Google Maps' StreetView function enables the close examination of the studied landscape ('zooming in and out'), while the timeline features allow for a visualisation of the changes that have occurred in space over time (Carleton College, 2018).

GPS devices. In this study, GPS devices are hand-held devices that utilise the Global Positioning System to access data relating to the device's location. While professional-grade GPS remain a costly investment, teachers can make use of the GPS capabilities embedded in students' own technology, particularly smart-phones, iPads and other popular personal technologies. GPS devices can be particularly useful tools in geography fieldwork settings, allowing students to accurately measure the location of geographical phenomenon observed and studied (Welch, France, Whalley & Park, 2012).

Teachers' use of geospatial technologies within their teaching practice can vary in complexity with respect to both the different types of GST used and the affordances of the applications or platforms associated with the technologies. Reflecting this understanding, Sui (1995) proposed a model for explaining how and for what purposes teachers should utilise GIS with their students. Sui asserted that GIS education consists of two components – teaching *about* GIS and teaching *with* GIS. Teaching *about* GIS involves teaching the fundamental technical skills to operate and make use of geospatial technology and their associated applications, while teaching *with* GIS is about the purposeful use of the technology for learning discipline-specific content (i.e. geography concepts). While Sui suggested that both forms of teaching are important for quality GIS education, it was teaching *with* GIS that should be prioritised. As Sui argued, "GIS technology should not be as an end in itself. Instead it should be a means to a higher end… to have a more thorough understanding about human-environment interaction and various physical processes" (p. 587). Sui's argument was made in response to his reflections on tertiary-level GIS education, however, his model has been consistently adopted by GST education researchers in K-12 contexts and initial teacher education (see, for example, Baker & Kerski, 2014; Baker et al., 2015; Harte, 2017; Hong, 2015). These researchers have adopted Sui's model to explain how different geospatial technologies offer different opportunities for teaching that can vary in sophistication and complexity.

Sui's model helps to explain the different ways that teachers can make use of geospatial technologies within the *Australian Curriculum: Geography* requirements. An in-depth demonstration of the curriculum requirements is situated within Chapter Two (see pp. 40-45), however, the curriculum requires students to engage with both geospatial data (such as GPS coordinators, satellite and aerial photography) and geospatial technology applications or platforms (like Google Earth, Google Maps and GIS). GPS coordinates, satellite and aerial photography constitute raw geospatial data. In the classroom, the data can be visualised on basic GST applications and platforms like Google Earth and Google Maps and limited functions, like measuring distances and ‘zooming in and out,’ can provide opportunities for students to draw basic conclusions about the spatial distribution of the data. Such uses of geospatial data and GST platforms can allow students to develop some fundamental geospatial skills, such as collecting and observing geospatial data, and the basic technical skills needed to visualise data through platforms like Google Earth and Google Maps. These uses align with Sui’s (1995) conception of teaching *about* GIS where the learning is limited to acquiring the technical skills needed to perform these functions.

GIS, on the other hand, can also be used by teachers to enable more sophisticated forms of geographical analysis, including the creation of digital maps and thematic overlays based on geospatial data that can be imported into the platform from primary or secondary sources. GIS is an analytical tool; the functions of GIS enable complex querying of geospatial datasets. Research supports the contention that the adoption of GIS in classrooms can enable sophisticated geographical analysis. Recent studies have suggested that GIS-based geography teaching can be very effective in developing students’ higher-order cognitive processes and their skills of critical geographical analysis (Metoyer & Bednarz, 2017; Favier & van der Schee, 2014). In these studies, the participants exemplified practices of teaching *with* GIS, underscoring the value of this technology in improving students’ geographical thinking and learning about geography content.

It is worth noting that, while the current iteration of the *Australian Curriculum: Geography* reflects opportunities to for students to learn geography through the application of Remote Sensing, GPS and GIS, the nature of both curriculum and technology means that these requirements may very well shift or change in the future. Stinson (2007) appropriately described curriculum development as “shifting sand” (p. 6); that is, the curriculum is fluid, subject to modification and revision based on emerging political priorities, changing societal values, and pedagogical innovation (Brennan, 2011; Seddon, 2001; Voogt & Pelgrum, 2005). Likewise, continuous technology development into the future will undoubtedly have flow-on effects for educational contexts (Collins & Halverson, 2010). Accordingly, the content of the Australian geography curriculum and the technologies that teachers are required to use for teaching that curriculum are likely to continue to evolve. There could be, for example, future requirements for teachers to make use of emerging technologies, like augmented and virtual reality, for geography teaching. Indeed, recent research has pointed to the potential value of ‘serious games’ (such as simulation and role-play games) for teaching geography concepts and developing students’ geographical thinking (see, for example, Bartoschek, Schwering, Li, Münzer & Carlos, 2018; Favier & van der Schee, 2014; Wouters, van Nimwegen, Oostendrop & van der Spek, 2013). While these technologies are not currently mentioned within the *Australian Curriculum: Geography* framework, this is not to say that these technologies will not feature in a future iteration of the curriculum nor that more innovative geography teachers will not begin to make use of these technologies in their teaching ahead of any future curriculum mandate.

1.7.3 Secondary Geography Education

This research is concerned with geospatial technology use within geography education in Australian secondary schools. It is important to note that the structure of secondary schooling differs throughout Australia. Collectively, participants in this research reported having taught geography in each state and territory of Australia. It is necessary, therefore, to examine the structure of secondary education in the states and territories to highlight variations in the contexts in which early adopters of GST are teaching geography. Variations in secondary schooling are represented in Table 1.1.

Table 1.1

Secondary School Education in Australia

Year Level	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Australian Capital Territory	P	Secondary				College	
New South Wales	P	Secondary				Senior Sec.	
Northern Territory	P	Secondary				Senior Sec.	
Queensland*	P	Secondary				Senior Sec.	
South Australia	P		Secondary			Senior Sec.	
Tasmania	P	Secondary				College	
Victoria	P	Secondary				Senior Sec.	
Western Australia*	P	Secondary				Senior Sec.	

Note. P = primary school, *Queensland and Western Australia have made recent changes to the structure of secondary education. From 2015, Year 7 was moved from primary to secondary education in both states.

Variations in the schooling structures across Australia have implications for this research. While the bulk of research data were collected in 2015 (after Queensland and Western Australia moved Year 7 to secondary school), teachers from Queensland, Western Australia and South Australia, when asked to reflect on their practices of using GST for secondary education, may have excluded their past experiences teaching Year 7 students from their responses. Similarly, teachers from

Tasmania and the Australian Capital Territory may not have reported on experiences teaching college students (Years 11 and 12) as they may not consider Year 11 and 12 to be a part of secondary education.

1.8 Thesis Structure

The structure of this thesis allows for the examination of the individual and collective teaching practices of teachers who use geospatial technologies to teach secondary school geography in Australian schools. First, the practices of all surveyed teachers (*n*=53) are considered through an analysis of survey data. Second, the practices of individual teachers (*n*=8) are investigated through semi-structured interviews and an examination of their teaching artefacts (worksheets, lesson plans and other exemplars of their teaching). To accommodate this structure, the thesis is divided into 10 chapters

The structure of this thesis is as outlined:

Chapter One presents an overview of the research and describes the research problem in relation to the renewed emphasis on geography education within the *Australian Curriculum* and the inclusion of GST as tools for teaching geography knowledge and skills.

Chapter Two presents a discussion of the place of GST within *Australian Curriculum: Geography*. The chapter highlights the centrality of technology to the discipline of geography and identifies current trends within GST education research.

Chapter Three examines the theoretical perspectives that inform this research. First, the Technological, Pedagogical and Content Knowledge (TPACK) framework (Mishra & Koehler, 2009) and TPACK context adaptations advanced by Porras-Hernández and Salinas-Amescua (2013) are described. Second, the Diffusion of

Innovations Theory is explained, particularly identifying the role of early adopters in the diffusion of an innovation. The relevancy and utility of these frameworks for this research is also established in this chapter.

Chapter Four describes the sequential explanatory mixed-methods research design, survey instrument and interview protocols used to collect data for this research. The research analysis strategy is presented and the procedure for integrating quantitative and qualitative research findings is described.

Chapters Five, Six, Seven, Eight and Nine constitute the presentation and discussion of the findings of this research.

Chapter Ten concludes the thesis by summarising the findings and contributions of the research, identifying study limitations, and the opportunities for further research.

1.9 Summary

The ‘problem’ of geospatial technologies in *Australian Curriculum: Geography* was the impetus for this study. The existing research has indicated that geospatial technologies are not commonly used in geography education and that a range of barriers exist to teachers’ adoption of these technologies (Baker, 2015; Baker & Langran, 2016). This study examined the teaching practices of some teachers (early adopters) with the purpose of identifying opportunities and possibilities for greater GST adoption amongst Australian geography teachers.

The theoretical frameworks which informed this research are the Technological, Pedagogical and Content Knowledge (TPACK) framework (Mishra & Koehler, 2009) and the Diffusion of Innovations theory (Rogers, 2003). These theories were used throughout the study to identify early adopters’ knowledge for teaching geography with GST and the contribution of early adopters to the spread of GST within schools.

This study was designed to address key gaps within the existing research literature regarding teachers' practices in using GST in geography teaching, teachers' knowledge for teaching with GST and the conditions that influence and enable teachers to adopt these technologies in the classroom. In the next chapter, this thesis turns to consider the findings of existing GST-education literature and provides justification for the study's research questions.

Chapter 2

Geography Education and Geospatial Technologies

2.1 Introduction

The theoretical heart of this study lies at the intersection of three key research fields: geography education, technology use in teaching, and teaching change and innovation. This chapter serves as a review of relevant literature drawn from each of these research fields. It synthesises the insights provided by the literature to delineate the ‘research gaps’ that define the parameters of this study.

As the impetus for this study was the recent inclusion of geospatial technologies in *Australian Curriculum: Geography*, this chapter begins with an overview of the curriculum and the opportunities that exist for teachers to utilise GST in their teaching of secondary geography.

2.2 *Australian Curriculum: Geography*

The development of an Australian curriculum from 2011 onwards established geography as a mandatory subject in secondary schools. Prior to the *Australian Curriculum*, geography was predominantly taught in Australian secondary schools under the interdisciplinary framework of Studies of Society and Environment

(SOSE)/Social Science (otherwise termed Human Society and Its Environment or Society and History) (Casinader, 2016). Proponents of geography education argued that the SOSE curriculum framework “diluted the degree, breadth and depth of geographical education” (Casinader, 2015, p. 95). Thus, the introduction of the *Australian Curriculum: Geography* has been seen by some as indicative of a strengthening of geography teaching within Australian schools (Maude, 2014). The development of the separate geography curriculum addressed concerns raised by Hutchinson (2006) that geography education had been “marginalised” (p. 195) in Australian schools within the SOSE framework, resulting in declining student retention in post-compulsory geography subjects (AGTA, 2007; Erebus International, 2008).

Geography’s ‘marginalised’ place with the SOSE curriculum framework has perhaps had further implications for the preparedness of today’s Australian teachers to teach geography knowledge and skills to their students. The majority of secondary school geography teachers are teaching ‘out of area’, that is they are not geography specialists (Weldon, 2016). Lambert and Balderstone (2010), reflecting on the status of geography teaching in England, argued that “geography is openly attacked for somehow failing to box the same intellectual ‘weight’ as related subjects such as history” (p. 2). These observations appear to also ring true in the Australian educational context. Tambyah’s (2009) analysis of pre-service teachers’ identities found that more than double the number of humanities and social sciences secondary pre-service teachers identified as history teachers rather than geography teachers, despite studying for a degree that would qualify them to teach both subjects.

There are clear political and economic motivations for enhancing the place of geography within the *Australian Curriculum* framework. A recent report commissioned by the Department of Resources, Energy and Tourism (Lawrence, 2011), found a shortfall of Australian workers skilled in the collection and analysis of geospatial information. The report concluded that this lack of Australian skilled geospatial professionals placed Australia at a competitive disadvantage in key industries, such as mining, energy and heavy metals sectors. A further report produced by the Cooperative Research Centre for Spatial Information (ACIL Tasman, 2013) predicted that Australia would experience a shortfall of 1,512 surveyors and 608 spatial scientists by 2019. Encouraging young Australians to pursue these spatial science-related career paths will be an economic imperative in future years. In examining the adoption of geospatial technologies amongst Australian secondary geography teachers, this study was conducted within this political and economic context.

Beyond this economic rationale, the study of geography also serves to equip students with the knowledge and skills that will help them to understand and engage with their physical and social worlds. Increasingly, geographers and scientists, through their research, are bringing to light disturbing trends in climate and environmental change and these findings are being interpreted and construed by the media and political representatives to suit particular agendas (Boykoff, 2007; Olausson, 2011). Knowledge of geography and the capacity to consider issues from a geographical perspective will continue to be a fundamentally important component of young people's education, allowing them make sense of geographical information and discourses and to develop the skills to engage with spatial and place-based issues in informed ways.

2.2.1 Geospatial Technology Opportunities in *Australian Curriculum: Geography*

The use of geospatial technologies as a tool for teaching geography is a relatively new requirement for many Australian geography teachers. With the exception of South Australia's (2004) *R-10 Society and Environment Curriculum,* which recommended the use of geospatial technologies for geography teaching relatively early, the inclusion of GST within *Australian Curriculum: Geography,* implemented in schools from 2014, seems to have been the first time that many geography teachers had had these technologies signposted as essential pedagogic tools and an area of curriculum focus in geography education. In these early stages of curriculum implementation (NSW, for example, did not implement its version of the *Australian Curriculum: Geography* framework until 2017), it stands to reason that the current teaching practices of Australia's geography teachers may not yet include GST. It is important, then, both as context to this study and to provide evidence of these new curriculum requirements, to identify opportunities for geospatial technologies to be used in geography teaching in Australian secondary schools.

The opportunities for geospatial technologies within *Australian Curriculum: Geography* are borne out of the curriculum's focus on geographical inquiry as the methodology which underpins geography teaching and learning. The Australian Curriculum, Assessment and Reporting Authority (ACARA, 2016), Australia's national curriculum-making body, defines geographical inquiry as:

> … involv[ing] skills needed to formulate questions and initiating, planning and implementing a relevant inquiry of a geographical issue, process or phenomenon.

By engaging with the geographical inquiry methodology, students are required to pose geographical inquiry questions, collect, record and evaluate geographical data, make judgements and draw conclusions, communicate and reflect on their conclusions and suggest or undertake action. The geographical inquiry methodology is represented in Figure 2.1.

Geospatial technologies are particularly valuable for conducting the second and third stages of geographical inquiry: ‘collecting, recording, evaluating and representing’ and ‘interpreting, analysing and concluding.’ Accordingly, *Australian Curriculum: Geography* explicitly includes the use of geospatial technologies within the ‘Geographical Inquiry and Skills’ strand of the curriculum (ACARA, 2016).

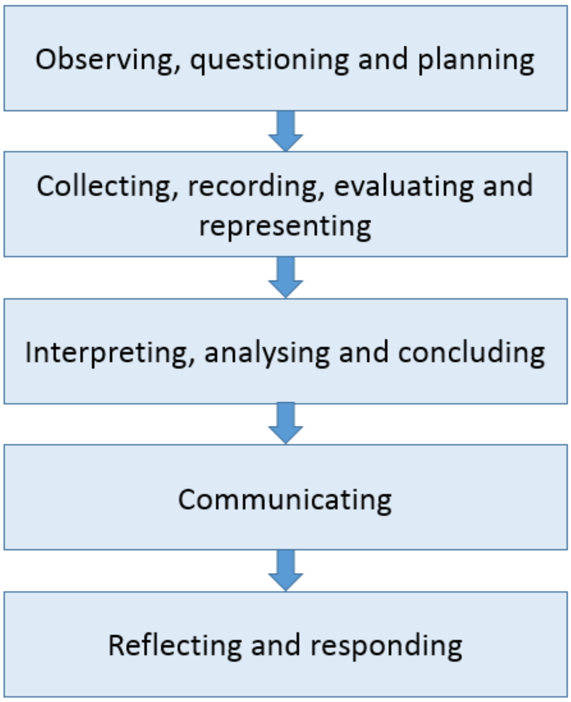


Figure 2.1. Geographical inquiry methodology, adapted from ACARA (2016).

To demonstrate the explicit connections between the Geographical Inquiry and Skills strand and geospatial technologies, relevant content descriptors from each year level and associated elaborations which speak to the use of GST in geography teaching and learning are represented in Table 2.1. As evidenced within the table, opportunities to utilise geospatial technologies are provided in each year level from Year 7-10. It is important to note that a number of terms are used in the curriculum documents to refer to geospatial technologies, such as ‘spatial technologies’, ‘computer mapping software’, and ‘digital maps and overlays.’ For ease of identification, references to geospatial technologies are in bold font in Table 2.1. Given the new curriculum requirements, this study is both timely and highly relevant in its investigation of how early adopters of GST use geospatial technologies in their teaching.

It is clear from the table that for schools and teachers prepared and interested in creating a plan for how students will develop and apply GST in the context of their geography learning, the scope for undertaking it in a progressive and pedagogically rich way is usefully signposted by *Australian Curriculum: Geography* content descriptors. However, ACARA’s (2016c) determination that only the curriculum content descriptors are mandatory for teaching and that content elaborations represent only “optional” learning opportunities within the curriculum framework may mean teachers are uncertain about ways of integrating GST and geography content. Indeed, the lack of consistency of nomenclature and the varying guidance around whether the use of geospatial technologies is optional or compulsory, could mean that schools and teachers may not see this as a priority.

Table 2.1

Opportunities for GST in Australian Curriculum: Geography

Year Level	Mandatory Content Descriptors	Optional Content Elaborations
7	Represent data in a range of appropriate forms, for example climate graphs, compound column graphs, population pyramids, tables, field sketches and annotated diagrams, with and without the use of digital and **spatial technologies** (ACHGS049)	
7	Represent spatial distribution of different types of geographical phenomena by constructing appropriate maps at different scales that conform to cartographic conventions, using **spatial technologies** as appropriate (ACHGS050)	Creating a map to show the spatial distribution and patterns of liveability, using **computer mapping software**
7	Interpret geographical data and other information using qualitative and quantitative methods, and digital and **spatial technologies** as appropriate, to identify and propose explanations for spatial distributions, patterns and trends, and infer relationships (ACHGS051)	Using graphs, weather maps and **satellite images** to examine the temporal and spatial patterns of a selected hydrological hazard in Australia and another region of the world (for example, countries of the Asia region or of the Pacific region); Using **digital maps and overlays** of an area to observe, describe and contrast the spatial associations of geographical phenomena (for example, the relationship between economic activities and river systems and the availability of surface water)
8	Represent data in a range of appropriate forms, for example, climate graphs, compound column graphs, population pyramids, tables, field sketches and annotated diagrams, with and without the use of digital and **spatial technologies** (ACHGS057)	
8	Represent spatial distribution of different types of geographical phenomena by constructing appropriate maps at different scales that conform to cartographic conventions, using **spatial technologies** as appropriate (ACHGS058)	Developing a statistical map to show demographic or economic data for Australia or China, or show the cultural and demographic diversity of Aboriginal and Torres Strait Islander Peoples **using mapping software**; Creating a map showing geomorphological features by using data from Geoscience Australia, or demographic statistics from

		census data, using a **spatial technologies application**; Using the **Global Positioning System (GPS)** to make a map of the features of a landform
8	Interpret geographical data and other information using qualitative and quantitative methods, and digital and **spatial technologies** as appropriate, to identify and propose explanations for spatial distributions, patterns and trends, and infer relationships (ACHGS059)	Using **digital mapping tools** to map the cultural and demographic diversity of Aboriginal and Torres Strait Islander Peoples
8	Present findings, arguments and ideas in a range of communication forms selected to suit a particular audience and purpose; using geographical terminology and digital technologies as appropriate (ACHGS061)	Presenting a report, supported by **spatial technologies,** to communicate a reasoned argument (for example, to advocate for actions to ensure that landscapes and seascapes can be managed sustainably for use by future generations)
9	Evaluate sources for their reliability, bias and usefulness and select, collect, record and organise relevant geographical data and information, using ethical protocols, from a range of appropriate primary and secondary sources (ACHGS064)	Collecting geographical information from secondary sources (for example, topographic maps, thematic maps, choropleth maps, weather maps, climate graphs, compound column graphs and population pyramids, scatter plots, tables, **satellite images and aerial photographs**, reports, census data and the media)
9	Represent multivariable data in a range of appropriate forms, for example scatter plots, tables, field sketches and annotated diagrams, with and without the use of digital and **spatial technologies** (ACHGS065)	
9	Represent spatial distribution of geographical phenomena by constructing special purpose maps that conform to cartographic conventions, using **spatial technologies** as appropriate (ACHGS066)	Creating a map to show the relationship between biomes and world food production, using a **spatial technologies application**
9	Interpret and analyse multivariable data and other geographical information using qualitative and quantitative methods, and digital and **spatial technologies** as appropriate, to make generalisations and inferences, propose explanations for patterns, trends, relationships and anomalies, and predict outcomes (ACHGS067)	
9	Identify how **geographical information systems (GIS)** might be used to analyse geographical data and make predictions (ACHGS069)	Identifying the relevant layers of a **geographical information system** and using them to investigate how they can portray and analyse demographic, economic and environmental data

10	Evaluate sources for their reliability, bias and usefulness and select, collect, record and organise relevant geographical data and information, using ethical protocols, from a range of appropriate primary and secondary sources (ACHGS073)	Collecting geographical information from secondary sources (for example, topographic maps, thematic maps, choropleth maps, weather maps, climate graphs, compound column graphs and population pyramids, scatter plots, tables, **satellite images and aerial photographs**, reports, census data and the media)
10	Represent multivariable data in a range of appropriate forms, for example scatter plots, tables, field sketches and annotated diagrams, with and without the use of digital and **spatial technologies** (ACHGS074)	
10	Represent spatial distribution of geographical phenomena by constructing special purpose maps that conform to cartographic conventions, using **spatial technologies** as appropriate (ACHGS075)	Creating a map to show measures of environmental change, using a **spatial technologies application**
10	Interpret and analyse multivariable data and other geographical information using qualitative and quantitative methods, and digital and **spatial technologies** as appropriate, to make generalisations and inferences, propose explanations for patterns, trends, relationships and anomalies, and predict outcomes (ACHGS076)	Analysing environmental change (for example, the clearance of vegetation or a plan for a vegetation corridor) using topographic maps and **satellite images**
10	Identify how **geographical information systems (GIS)** might be used to analyse geographical data and make predictions (ACHGS078)	Outlining how **geographical information systems (GIS)** are used in environmental management or in analysing spatial patterns of human wellbeing; Investigating the use of **geographic information systems (GIS)** by Indigenous peoples in Australia and elsewhere for managing conservation

2.3 Twenty-First Century Geography Education

The development and implementation of *Australian Curriculum: Geography* has been contemporaneous with on-going dialogues between researchers, policy-makers and practitioners about the nature and purposes of geography education in the twenty-first century. Increased global interdependency, rapid technological advances, over-population and competitive economic systems have led to complex environmental, social and economic challenges at local, national and global scales (Harper & Snowden, 2017; Uniyal, Kaphaliya, Paliwal & Sharma, 2017). A growing body of international and Australian research argues that geography education, and the particular ways of thinking that geography engenders (geographical thinking), can play an integral role in equipping individuals with the capacity to critically engage with these pressing challenges (Maude, 2015; Stoltman, Lidstone & Kidman, 2015; Young, Lambert, Roberts & Roberts, 2014). More specifically, this research contends that the specialised knowledge that can be gained through the learning of geography empowers learners to both appreciate and develop the social agency to act on these twenty-first century challenges.

Within this research, Young's (2008) concept of 'powerful knowledge' has been used to identify and explain how and why geography content knowledge must be conceived of as more than mere knowledge of 'capes and bays.' Instead, powerful geography knowledge provides a window through which students can make sense of the world around them and its complex problems, in turn enabling them to participate in public discourse surrounding these issues. As argued by Young (2008), powerful knowledge:

> … refers to what the knowledge can do or what intellectual power it gives to those who have access to it. *Powerful knowledge* provides more reliable explanations and new ways of thinking about the world, and acquiring it can provide learners with a language for engaging in political, moral, and other kinds of debates (2008, p. 14, original emphasis).

Young's powerful knowledge concept has been taken up by researchers in a variety of education fields, including history and science, engineering and technology (STEM) education (see, Counsell, 2011; Young & Muller, 2015; Wrenn, 2010). Powerful knowledge has a clear home within geographical education. The various lenses through which the discipline of geography examines the world (i.e. historical, scientific, cultural, and economic) can help students to develop deep, multifaceted understandings of contemporary environmental, social and economic problems.

Geography education provides students with opportunities to grapple with contemporary geographic issues such as climate change, overpopulation, resource exploitation and food security (International Geographical Union Commission on Geographical Education, 2016). Learning geography enables an appreciation of the ways in which physical geographical processes have shaped the Earth's surface, as well as the role and impact of humans in adapting to and changing the environment for survival and cultural, economic and political purposes (AGTA, 2017). This rationale underpins the design of *Australian Curriculum: Geography* and demonstrates the valuable insights and perspectives that can be gained through geography education.

The emergence of these complex problems requires more nuanced and increasingly techno-centric ways of expressing and acting upon powerful geography knowledge. Technological advances have had a transformative effect on geography as a subject discipline. The development of technologies which allow users to access geospatial information in ‘real-time’ has fundamentally altered how geographers (and the businesses and governments that they work for) perform (Richardson, 2004). Indeed, Deloitte’s (2015) *Future of Government* (*Gov2020*) study recently found that geographers will increasingly play a critical role in managing a diverse range of public services, such as traffic management, infrastructure management, transportation, law enforcement and agriculture. It is through the use of geospatial technologies, and the real-time geographical analysis and decision-making that they enable, that geographers find themselves uniquely positioned to respond to the critical challenges facing today’s world.

Geography teacher, Patrick Wiegand, in his keynote address to delegates at the International Geographical Union Conference (2004) underscored a critical need for geographical education to “keep pace” (p. 34) with this broader turn towards geospatial technologies within geography. In an era where maps, and the ways in which individuals access maps, are becoming increasingly digitised, geography education must provide students with the skills to interpret digital spatial representations and digital maps to ensure they can use them purposefully in their daily lives. As Weigand argued, geography teaching must work to generate powerful geographical knowledge though the teaching of map *using*, rather than map *reading*.

2.4 Geography Teaching

Geography teachers are the gatekeepers of the powerful geography knowledge that students need to engage with while thinking about twenty-first century challenges. Solem, Lambert and Tani (2013) extended the powerful knowledge concept through their development of a "capabilities approach" (p. 214) to geography education (termed GeoCapabilities by the authors).

2.4.1 GeoCapabilities

The GeoCapabilities approach attempts to capture the ways in which teachers can teach and share powerful geography knowledge with their students. According to the researchers,

> … a capabilities approach to education considers how the individual can lead a life that she or he has reason to value. A *Geo*Capabilities approach argues that an individual will develop greater potential to do this if they acquire geographical knowledge, enabling them to think geographically (GeoCapabilities, 2016, para. 5, original emphasis).

GeoCapabilities emphasises the central role of teachers in supporting and empowering students to exercise autonomy, to think and reason, to make choices in their lives and to understand their place in the world through geographical thinking (Lambert, 2017; Lambert, Solem & Tani, 2015; Uhlenwinkel et al., 2017). Teachers act as "curriculum-makers" (Lambert et al, 2015, p. 723) in designing and creating learning opportunities that bring together their own knowledge and skills, students' lived experiences, and the knowledge, concepts and ideas that are central to geography as a subject discipline (Geographical Association, 2014, para. 1). In transforming geography curriculum standards into meaningful and purposeful expressions of the subject, teachers can enable students to gain powerful geography knowledge.

Accordingly, geography teachers and the ways in which they teach geography are fundamental in supporting students to gain powerful geography knowledge.

Indeed, Favier (2011) argued that teachers' geography knowledge and their capacity to "translate" (p. 279) geography theories into student-accessible content was critical to the development of students' geography knowledge and ability to think geographically. It is, therefore, teachers' capacity to represent geography knowledge in ways that are meaningful for students that allows these students access to the specialised geography knowledge to which Lambert and colleagues speak.

2.4.2 Geography Teacher Knowledge

Concerns have been raised about the degree to which geography teachers have the knowledge and skills to adopt a GeoCapabilities approach to teaching geography. In recent years, there has been questions raised within the geography education community about the geography content knowledge of teachers used to teaching in broader interdisciplinary 'social studies' contexts. These teachers are now charged with teaching geography as a discrete subject within the *Australian Curriculum* framework (Australian Geography Teachers' Association, 2007; Hutchinson, 2006). As many past social studies teachers are likely to hold educational backgrounds in subjects other than geography (e.g. history, business, economics), this concern is not without merit. What is the geography knowledge of geography teachers? What geography knowledge do teachers need to possess to be able to teach geography to their students? These questions have been the central line of inquiry of some recently published studies (see Bourke & Lidstone, 2015; Lane, 2011). The results of these studies highlight the complex nature of teacher knowledge for teaching geography and competing tensions and discourses within the research about what defines good geography teaching.

The *Australian Curriculum* provides a clear account of the geography knowledge that Australian geography teachers will need to teach their students. The development (and subsequent evolution) of the *Australian Curriculum: Geography* has been driven by a range of stakeholders whose input into curriculum design determined the range and breadth of the geography topics and skills covered. Recent changes to the primary-level curriculum (that is, the introduction of F-6 HASS) have resulted in a reduction in geography content within the primary curriculum and a greater focus on integrating and aligning geography content with history and civics and citizenship learning. For secondary geography teachers, the core geography topics and concepts to be covered in Years 7-10 have remained relatively unchanged during recent updates to the curriculum.

To identify the geography knowledge that teachers need to possess and to teach their students, Bourke and Lidstone (2015) conducted document analysis on the previous F-6 geography curriculum. Although superseded by the introduction of primary HASS, the authors' analysis nonetheless identified a series of dominant discourses within the curriculum which are evidence of the types of geography knowledge that teachers will be expected to teach and the progression of learning of geography concepts and skills taught in Australian schools. Bourke and Lidstone found the discourse of 'place' was most dominant within the F-6 curriculum with the term 'place' appearing 144 times. Within the *Australian Curriculum*, the study of place includes learning about: how and where people live; how place contributes to our sense of identity and belonging; how to care for places; the variations in the size of different places; similarities and differences between places; and the interconnections between places in a globalised world (p.6). The discourse of 'environment' was also found to be dominant within the curriculum with learning emphases upon the relationship between the environment and the sustainability of the human and natural world (p. 6). Minor discourses of ‘space’ (e.g. how space is arranged within places), ‘scale’ (defining places by scale) and ‘sustainability’ were also identified (p. 6). These concepts, which first appear in the F-6 curriculum, are further explored in the secondary school. In Years 7-10, students develop more critical understandings of these concepts, applying them in the study of variety of places and environments at a range of scales (local to global) (ACARA, 2016).

Research evidence is thin, however, with regards to the geography knowledge possessed by Australian geography teachers. Rod Lane’s (2011) study of the knowledge of sixteen experienced Australian geography teachers about tropical cyclone causes, patterns and processes provides some research-based evidence of the geography knowledge of Australian geography teachers. Utilising a mixed-research methodology, Lane collected data from questionnaires and semi-structured interviews to measure the accuracy of teachers’ knowledge and their depth of understanding about tropical cyclones. Lane determined that, while the factual and conceptual knowledge of the geography teachers was “generally sound” (p. 54), some concepts (such as evaporation, air pressure, and reasons for latitudinal temperature differences) were not as well understood by teachers. Although Lane’s sample was limited to experienced geography teachers who had both an undergraduate education in Geography and had previously taught about tropical cyclones in their geography classes, the study nonetheless provides evidence to support claims that geography teachers may not possess the geography knowledge they need to teach the *Australian Curriculum* requirements. Lane’s findings beg the question: what is the geography content knowledge of teachers who do not have a tertiary background in Geography? Considering the transition of many teachers from teaching a social studies-style integrated curriculum framework to the *Australian Curriculum: Geography*, such questions will become increasingly important for preparing and developing Australia's current and future geography teaching workforce.

Concerns about the geography knowledge of geography teachers is also evident at an international scale. Mitchell and Lambert's (2015) research in England highlighted how teachers' roles are increasingly multifaceted and bureaucratised within the contemporary education systems, impacting on the geography knowledge and skill development of teachers and the quality of their geography curriculum. The researchers made a strong argument that today's teachers are expected to be "skilled technicians" (p. 366) focused on meeting performance standards and competencies rather than subject experts. As such, the researchers argued that performance pressures undermined teachers' capacity to create curricula with a strong grounding in geography content. Mitchell and Lambert drew three conclusions about geography teaching in today's schools: first, the process of teaching is given greater emphasis than geography content; second, teachers are too preoccupied with engaging students by connecting geography ideas to their past experiences (to the detriment of learning new geography knowledge); and, finally, the teaching of social issues is often misrepresented as the teaching of geography knowledge. According to Mitchell and Lambert, "concern for pedagogy appears to have overridden curriculum thinking…" (p. 370) and the researchers called for a return to a knowledge-based curriculum that lends a more equal weighting to geography content knowledge and pedagogy:

> We argue that learning to teach a school subject (geography in this case) requires new teachers to develop their knowledge of both subject discipline and educational processes. They engage with two big ideas – geography and education – and through the concept of curriculum and

> curriculum making, new teachers can do this in a practical context and with balance… (p. 377).

Mitchell and Lambert (2015) are amongst a growing number of researchers and professionals in the geography education community who call for geography teachers to have knowledge of a shared body of geography content and skills (Morgan & Lambert, 2005; Rynne & Lambert, 1997; Tambyah, 2006). For these geography education advocates, possession of 'core' or fundamental knowledge of the discipline is essential for effective geography teaching. Teachers' possession of core geography knowledge, these authors argue, ensures that students learn the geography content and skills that will enable them to make reasoned choices in their lives, equipping them with the capacity to address the critical geographical challenges facing today's world.

2.5 Quality in GST Education Research

Research on the use of geospatial technologies in education is still largely in its infancy and is catching up to increasing technology innovation and school curriculum development. The proliferation of geospatial technologies in mainstream society is only just beginning to infiltrate school classrooms. Accordingly, previous research efforts thus far have been concerned primarily with establishing the field as an area of academic research (Baker & Bednarz, 2003; Baker et al., 2015), describing the potential for geospatial technologies in education (Aladağ, 2010; Baker, 2005; Demirci, Karaburun & Kilar, 2013) and evaluating teacher professional development programs (Baker, Palmer & Kerski, 2009; Benimmas, Kerski & Solis, 2011; Doering, Veletsianos, Scharber & Miller, 2009; McClurg & Buss, 2007).

Given the need for education researchers to first establish the field, it is not surprising that some of the most prominent researchers in the field call for further, high-quality research to be conducted. There have been few designed and validated research instruments to collect data about geospatial technology education. Baker et al. (2015) argue that the development of the field has been constrained by research of poor quality which has neglected the importance of educational theory in research. Unfortunately, Baker et al.'s assessment of the field in 2015 echoes Baker and Bednarz's earlier (2003) evaluation of GST education research. In their commentary in a special edition of the *Journal of Geography*, Baker and Bednarz made a plea for research that was methodologically sound, informed by theory and grounded within the existing literature. The authors argued that many articles submitted for the journal "included no articulated research methodology, no research design, no central line of inquiry, and little connection to the literature, either in GIS or education" (2003, p. 233). In 2015, Baker et al. believed that little had changed in the preceding 12 years. Much of the existing GST education research, the authors argued, is "uninteresting, unreplicable, overly anecdotal, inaccessible or unknown to interested scholars in cognate disciplines, or impossible to implement and apply" (p. 119). It is clear that further research in this field is much needed.

2.6 Teaching with Geospatial Technologies

Research considering the pedagogical application of geospatial technologies in K-12 education began to emerge in the late twentieth-century. Myer, Butterick, Olkin and Zack (1999) provided one of the earliest commentaries about teaching and learning with GST in their analysis of the use of geographic information systems in American high schools. At that time, the authors concluded that while GIS might become a useful teaching tool in future, significant barriers to the use of the technology, such as the complexity of the software, made for a "steep learning curve"

(p. 576) for students and teachers attempting adoption. Other early studies also found considerable barriers to GIS adoption, resulting in little motivation and limited opportunities for teachers to use the technologies in their teaching (Audet & Paris, 1997; Lemberg & Stoltman, 1999; Kerski, 2001). The identification of various barriers to geospatial technologies in school teaching has been a consistent theme within the existing literature, especially literature published in the past decade (Baker, Palmer & Kerski, 2009; Kerski, 2003; Yap, Tan, Zhu & Wettasinghe, 2008).

2.6.1 Barriers to Geospatial Technologies for Geography Teaching

Within the existing literature, barriers to geospatial technology use in teaching have been identified. Regularly cited barriers include limited teacher knowledge of GST, limited technology access in classrooms, limited instructional time for teaching with GST and a lack of administrative support within schools (Beeson, 2006; Kidman & Palmer, 2006; McClurg & Buss, 2007; Wiegand, 2001).

Limited teacher knowledge of GST. It is consistently reported in the research literature that teachers believe that they lack the knowledge and/or confidence in their ability to implement geospatial technologies in their teaching (Akinyemi, 2016; Bednarz & Bednarz, 2008; Demirci, 2009). It follows that, if teachers are unaware of how to use the technology or are not confident in their use, it is unlikely that they will adopt GST in their teaching. In their study of Victorian geography teachers, Wheeler et al. (2010) found that over 50% of their sample of 193 teachers indicated that they were not confident in their personal knowledge of geographic information systems. Although the authors' sample was skewed towards more experienced teachers and, thus, perhaps did not reflect newer initial teacher education graduates at the time, the results are nonetheless consistent with other contemporary research studies.

Kinniburgh (2008) found 61% of his sample of New South Wales geography teachers (n = 34) similarly lacked confidence in their ability to develop GIS resources for teaching.

A recent study conducted by Hammond et al. (2018), which examined teachers' pedagogical content knowledge and knowledge for teaching with GST in an environmental science learning context, found teachers' use of GST and capacity to teach curriculum-relevant mapping experiences to their students was possible only after targeted professional development experiences. After professional development sessions teachers showed growth in their ability to use maps for inquiry-based learning which represented a shift away from the didactic/direct instruction approaches they were previously employing in the classroom. While Hammond et al.'s sample size was very small (n=4), it nonetheless indicated that well-designed professional development experiences could lead to changes in teacher pedagogy.

Given the time that has elapsed since the early studies of Australian teachers' GIS/GST knowledge, in addition to the inclusion of GST within *Australian Curriculum: Geography*, increased public access to GST via web and mobile devices, and research that indicates the value of GST-focussed professional experience, pertinent to determine whether teachers' knowledge and confidence about these technologies still remains a relevant barrier to GST adoption.

Limited technology access in classrooms. A lack of availability of technology resources, particularly related to the accessibility of computers in the classroom and the high bandwidth demands of professional GIS software, has been a well-cited barrier to geospatial technology adoption (Lam, Lai & Wong, 2009; McClurg & Buss, 2007). In schools without access to computers within the classroom environment, the demand for communal computer labs amongst classes has been seen as a deterrent to

GST-enhanced teaching. Similarly, dated computer hardware which did not meet the operating requirements of the then-commercially available GIS packages also greatly inhibited teachers' ability to adopt the technology in their teaching (Baker, 2005; O'Dea, 2002).

Before the advent of free, web-based and/or open-source geospatial technology applications, GIS packages were perceived by teachers to be too costly (Beeson, 2006; Brodie, 2006), thus reducing their capacity and motivation to adopt the technology in their practice. Similarly, the limited availability of datasets to use in classroom and a lack of ready-made, accessible and pedagogically realistic lesson plans were also identified as a barrier (Baker, 2005; Höhnle, Schubert & Uphues (2010) at this time. Kidman and Palmer (2006), in their reflections on the successful implementation of a GIS program in one Australian school, determined that a partnership between the school and local government allowed the teacher access to a range of GIS datasets that could be used for teaching. The study provided further weight to the argument that a lack of resources hinders teachers' use of GST and also indicated that the provision of relevant GIS datasets could enable teachers to more successfully make use of the technology for teaching.

Limited instructional time for teaching with GST. As with any new practice, teachers must learn to operate geospatial technologies, consider the pedagogical applications of the technologies to their subject, and plan lessons incorporating the technology before they can teach it to their students. Many of today's teachers may engage with geospatial technologies on their smartphones or other devices, meaning that they may be more confident about their capacity to operate GST. Studies conducted in the early part of the twenty-first century, however, found that teachers were particularly constrained in their GST adoption by the time it took to learn the often-complex operations of professional GIS packages and to create or modify lesson materials for class (Dascombe, 2006; Lam et al., 2009; Meany, 2006).

A review of geography education in Australia published in the *International Research in Geographical and Environmental Education* journal determined that, at least prior to 2006, instructional time devoted to geography in Australian schools had been limited (Freeman, 2006; McInerney & Shepherd, 2006; Smerdon, 2006). Teaching geography within the SOSE framework provided for a "crowded curriculum" (Wheeler, Gordon-Brown, Peterson & Ward, 2010 p. 167), meaning that specific instructional time for geography was minimal in the context of the broad, interdisciplinary learning in SOSE. While geography has fared better within the *Australian Curriculum* framework (50-60 hours per year recommended for Years 7-8, 60-80 hours per year recommended for Years 9-10 (ACARA, 2011)), it is evident that teaching with technology does require an investment of teachers' time both in the preparation and the teaching (Hew & Brush, 2007; Kale & Goh, 2014) and that limitations on teaching time compound the challenge of GST adoption.

Lack of administrative support within schools. Varying levels of support from school administrators can influence the use of technology in schools. Wheeler et al. (2010), in their study of GIS adoption in Victorian schools, discovered both a "bottom-up" resistance to GIS use from classroom teachers and a "top-down" lack of support from school administrators for their adoption (p. 154). This finding was supported by other contemporary studies which acknowledged the central role of support from school administrators in encouraging teachers' GST adoption (Baker, 2005; Dascombe, 2006; Smerdon, 2006). In anticipation of this barrier, McInerney (2002) called for a systematic approach to GIS adoption whereby teachers and administrators might adopt a comprehensive strategy to facilitate GIS in schools.

Such approaches appear to have had a positive outcome on GIS adoption. Brodie (2006), for example, reported on one school's successful GIS campaign which was spearheaded by a school administrator who had won a fellowship to trial GIS application in schools.

*Privacy concerns***.** A further barrier to GST implementation refers to concerns expressed by some in education about the safety of students while using the Internet and the potential for misappropriation of student/school data (Baker, 2015). Indeed, these concerns may be well founded with research indicating that in today's technologically-connected world, an individual's data may be maliciously collected without their knowledge (Conti, Dehghantanha, Franke & Watson, 2018; Lopez, Rios, Bao & Wang (2017). Increasingly, governments and school systems are developing policy frameworks that guide students' use of the Internet and determine what technologies can and cannot be used at school (see, for example, Tasmanian Department of Education's Social Media Policy (2014) or the NSW Department of Education and Training's Information Security Policy (2015)). Concerns about students' privacy and safety could negatively impact on teachers' motivations for implementing GST in teaching. As an element of the inquiry framework which drives the teaching of *Australian Curriculum: Geography*, students are required to collect geographical data from local fieldwork sites. The sharing of this data in online platforms, including students' location, photographs and other geo-referenced material, could potentially risk students' safety and privacy.

2.6.2 Enablers of Geospatial Technologies for Geography Teaching

Much of the existing research literature has been concerned with identifying the barriers to geospatial technologies and fewer studies have examined potential enablers of teachers' GST adoption. The inclusion of geospatial technologies in *Australian Curriculum: Geography* necessitates a shift away from this deficit thinking towards discovering potential opportunities to facilitate and support teachers' GST use. Some enablers have been identified in the literature, such as effective professional development, teacher-initiated support groups, teacher mentorship, and cross-disciplinary collaborative planning between teachers in schools (Baker et al., 2015; Beeson, 2006; Dascombe, 2006; Millsaps & Harrington, 2017). Fargher (2018) argues that increased public access to open-source data and mobile applications eliminates access barriers for teachers wishing to make use of GST. While the research is beginning to identify these potential enablers, there remains a need for further research to illuminate possibilities and opportunities for improving GST adoption amongst geography teachers.

2.6.3 Geography Teacher Standards

A promising potential enabler of geospatial technologies is the recently published *Professional Standards for Accomplished Teaching of School Geography* (*GEOGstandards*) (Mulcahy & Kriewaldt, 2016). Developed by respected geography education researchers from the University of Melbourne, the professional standards articulate nine competencies of accomplished geography teachers. Analysing extensive observations and interviews with high-calibre geography teachers and their students across Victoria, New South Wales and South Australia, the researchers found that accomplished geography teaching is that which "engages students in the classroom and in the field and is built on substantive knowledge of the discipline" (Mulcahy & Kriewaldt, 2016). The nine professional standards are:

1. Know geography and the geography curriculum.
2. Foster geographical inquiry and thinking.
3. Develop geographical thinking and communication.
4. Understand students and their communities.
5. Establish a safe, supportive and intellectually challenging learning environment.
6. Understand geography teaching and pedagogical practices.
7. Plan, assess and report.
8. Demonstrate on-going professional growth and development.
9. Learn and work collegially.

Achievement and/or efforts to achieve the professional standards could necessitate teachers learning about and adopting geospatial technologies. The use of geospatial technologies could, for example, be incorporated within teachers' practices to meet professional standards 1, 2, 3, 5, 6, 7 and 9.

It is worth noting, however, that the *GEOGstandards* reflect not just concerns about the knowledge and capacities of teachers to teach discipline-specific content though geography-specific pedagogies, but also represent a broader turn towards the standardisation of teacher practice in Australia. Indeed, only four of the professional standards are explicitly focused on geography teaching (standards 1, 2, 3 and 6), while the remaining standards are instead aligned to the generic expectations of teachers' practice as outlined in the *Australian Professional Standards for Teaching* (APST) (Australian Institute for Teaching and School Leadership, 2016). The APST, a nationally recognised set of 37 standardised expectations for practicing teachers against which all new teacher education graduates must demonstrate their competency (AITSL, 2016), are critical to teacher accreditation processes in Australia. The *GEOGstandards*, conversely, provide only guidance as to the expectations and practices of high-quality geography teachers and their teaching (Kriewaldt & Mulcahy, 2010). There is no requirement for geography teachers to demonstrate their capabilities against the *GEOGstandards.* There is, therefore, no national oversight to ensure that Australian geography teachers are engaging with the best-practice expectations contained with the *GEOGstandards.* Nonetheless, the development of a framework for identifying high quality geography teaching is indicative of efforts to enhance how geography is taught in Australian schools and does provide some scope for encouraging the use of geospatial technologies amongst geography teachers.

The *GEOGstandards* are part of an emerging matrix of standards about teachers' and students' use of ICT in education. The *Australian Curriculum* requires students to engage with ICT as part of the "general capabilities" that are embedded across the content of all key curriculum learning areas (ACARA, 2016). Likewise, the APST (particularly, standards 2.6, 3.4 and 4.5) (AITSL, 2016) illustrate the requirement for teachers and students to use ICT for teaching and learning purposes. The development of these standardised frameworks provides a clear rationale for the uptake of geospatial technologies in geography teaching, as a discipline-specific means of employing ICT in teaching.

2.7 Effectiveness of GST in Geography Teaching

In including geospatial technologies in *Australian Curriculum: Geography*, the curriculum-makers at the Australian Curriculum, Assessment and Reporting

Authority have clearly indicated their belief that the use of geospatial technologies in geography education is both central to the discipline of geography and can support students' learning of geography concepts and skills. Indeed, in addition to identifying barriers (and some enablers) of teachers' use of geospatial technologies, the existing research literature has also attempted to establish the validity and effectiveness of geospatial technology in school teaching. In particular, the research has consistently pointed to two benefits of geospatial technologies adoption: students' enhanced spatial thinking abilities and geography content knowledge and increased interest and motivation for studying geography (Artvinli, 2010; Nugent, Barker, Grandgenett & Adamchuk, 2010).

2.7.1 GST Enhances Spatial Abilities and Geography Content Knowledge

Geography education research indicates there is a critical need to find ways to enhance the teaching of geography through more innovative pedagogies. This includes a move away from a reliance on textbook material. Jo and Bednarz (2009), provide evidence to support this contention. The authors examined questions found in high-school level geography textbooks in the USA to evaluate the degree to which the questions encouraged spatial thinking. Their findings revealed that most textbook questions focused on low-level spatial thinking skills and spatial concepts and fewer questions required students to create spatial representations. Additionally, there were very limited opportunities for students to engage with higher-order spatial thinking skills. These findings are supported by those of researchers in the USA and in other countries (e.g. Alam (2017) in India; Government Accountability Office (2015) in the USA; Graves and Murphy (2000) and Lee and Catiling (2017) in England) who found many geography textbooks to be of poor quality, focused primarily on "closed" activities which do not allow for student-centred geographical inquiry or the development of critical and creative thinking skills. As the use of textbooks, both print and online versions, remains a strongly utilised pedagogical approach by geography teachers (ASCD, 2016; Xie & Luthy, 2017), the focus of many textbooks on lower-order geographical thinking presents a barrier to students' engaging in powerful geography knowledge and speaks to a need for teachers to adopt more innovative teaching approaches. Geospatial technologies could be an alternative approach to textbook-led geography teaching.

The primary motivation for adopting a new teaching practice must always be the betterment of student learning. Research efforts to have been made to establish the effectiveness of geospatial technologies in improving students' learning, including their geography content knowledge and spatial thinking abilities (Baker et al., 2015; van der Schee, Trimp, Békeker & Favier, 2015). Aladağ's (2010) study of the impact of GIS instruction on the learning of Turkish Year 7 geography students (*n* = 44) represents an early attempt to determine the effectiveness of GST for geography teaching. In her study, Aladağ found that students who received GIS instruction achieved higher average test scores than those students in the control group. Aladağ's early study, therefore, provided some evidence to support the contention that GIS is an effective tool for geography teaching and learning.

Other research conducted around the same time also found GIS to be an effective geography teaching tool. In their study of the effect of GIS use on the spatial abilities of American middle school students (*n* =156), Perkins, Hazleton, Erickson and Allan (2010) found that GPS devices and basic GIS functions could enhance students' abilities to produce spatially accurate maps of their school grounds from memory. Pre- and post-test data revealed that the use of GPS and GIS heightened students' capacity to represent relative area and relative distance more accurately. More recent research also supports the content that geospatial technologies can support students' geography learning. Favier and van der Schee (2014), for example, found evidence that geospatial technologies could improve students' geospatial reasoning skills, or their capacity to make reasoned arguments about "spatial distributions and patterns, spatial interactions, and spatial relations" (p. 226). In a science learning context, Bodzin, Fu, Kulo and Peffer (2014), in their study of the effect of a GST-enhanced learning sequence about energy consumption on the achievement of 1,177 Year 8 students, found geospatial technologies to be effective in improving students' geospatial thinking and reasoning skills and energy content knowledge. While finding evidence of the effectiveness of geospatial technologies in geography teaching must remain a critical objective of future research (Baker et al., 2015), evidence is mounting as to the value of geospatial technologies for enhancing students' geographical content knowledge and spatial thinking skills.

Research has also sought to compare the effectiveness of geospatial technologies with static paper maps on students' learning in geography (Collins, 2017; Metoyer & Bednarz, 2017). Metoyer and Bednarz (2017) investigated the effect of geospatial technologies on 41 high school students' spatial skills and capacity to learn a spatially-dependent concept (central place theory). During their intervention study, the authors concluded that students who used GST made greater gains in their spatially-dependent content knowledge than those who used paper maps. GST use also further enhanced the performance of those students who already possessed strong spatial skills.

Further evidence to support the use of GST in geography teaching is offered by Xian and Liu (2017) through their analysis of the effectiveness of Google Earth as a tool for teaching about the geographical concept of change and the skills of spatial thinking. Using an experimental design, the authors determined that students who learned using Google Earth showed greater improvements in their ability to identify geographical change (both spatial and temporal), were able to identify more changes and were able to better describe these changes than their peers who did not use Google Earth. Google Earth-based instruction was also found to increase students' willingness to make predictions about geographical change compared to their peers who experienced 'traditional' instructional methods. Xian and Liu's findings clearly indicated that Google Earth, which is a highly accessibly online tool, can be utilised by teachers in sophisticated ways to teach geography concepts. Teachers in the study made use of Google Earth's 'bird's eye view' function and embedded satellite imagery to better visualise geographical changes. The study provides strong evidence to support the contention that GST can enable deep geographical learning.

In the United States, a study examining the effects of participation in a GIS elective course on the standardised test scores of middle school (aged 11-13 years) children found significant gains in students' results in social science and science test scores, in addition to improvements in reading test scores (Goldstein & Alibrandi, 2013). In light of these results, the authors concluded that, as GIS positively influenced students' reading capabilities, the application of GIS in classrooms can equip students with the skills to construct knowledge in other subject areas, in addition to geography. These findings provide further evidence of the utility of GST within geography education and the secondary school curriculum more broadly.

It is important to recognise, however, that despite the positive associations between geospatial technologies and student learning reported in some of the research, there is still not a clear consensus among researchers about the effectiveness of geospatial technologies on student learning in comparison to other geography pedagogies. Jadallah et al. (2017), for example, concluded that instruction with GIS may be more effective than other geography pedagogies if the instruction was sustained over time. Collins (2017), in her study of the effects of GST on the learning of Year 8 students, determined that geospatial technologies were no more effective in increasing student learning than paper maps and the explicit teaching of spatial thinking skills These studies indicate that, while use of GST may be effective in enhancing student learning, teachers' choice of instructional methods is also influential. As van der Schee et al. (2015) argue, teachers' use of GST is "no guarantee for learning higher order thinking skills" (p. 17). Instead, *how* the teacher chooses to use GST in the classroom has a critical impact on the effectiveness of the technology for enhancing students' geography learning.

Indeed, the critical role of the teacher in planning and implementing effective GST-enhanced learning opportunities is highlighted in Jo's (2018) review of studies examining the teaching of spatial thinking in secondary school contexts. In particular, Jo's review of 13 research articles found that "the role that teachers play in successfully implementing innovative ideas in education, such as spatial thinking, cannot be overemphasised" (p. 211). Jo's findings accord with those of Hammond et al. (2018) who, in their analysis of the cartographic practices of teachers, determined that the promotion of spatial thinking and students' geographical analysis through the use of GST requires teachers understand how these technologies can be implemented in authentic classroom-based contexts. The success of GST-enhanced geography learning, therefore, is strongly correlated with teachers' capacity to utilise the technologies to inspire higher-order geographical thinking within their students.

2.7.2 GST Enhances Student Interest, Motivation and Engagement in Geography

Technology is often cited as a means of increasing student engagement in learning (Chao, Chen, Star & Dede, 2016; Fabian, Topping & Barron, 2016; Papastergiou, 2009). Motivation for learning has been identified as a critical ingredient in students' educational success (Hattie, 2008), therefore the use of geospatial technologies to engage students in geography learning does have merit.

Studies have sought to determine the extent to which geospatial technologies can motivate students in their geography learning. Aladağ (2010), in her study of Turkish students' attitudes towards GIS instruction, found that students who received GIS instruction perceived themselves to be more motivated in their learning than those students in the control group who received more 'traditional' geography instruction (textbooks and paper maps). Artvinli's (2010) findings are also consistent with Aladağ's findings; in his survey of 665 Turkish high school students, Artvinli determined that students were particularly motivated to learn using GIS and wanted more opportunities to use the technology in their classrooms.

Other international studies confirm an association between geospatial technologies and increased student motivation, interest and engagement in learning (see, for example, Berendsen, Hamerlinck & Webster, 2018; Nugent et al, 2010; Goldstein & Alibrandi, 2013). A more recent study by Hsu, Tsai and Chen (2017) found the use of Google Earth in the classroom, particularly when students were given the opportunity to examine physical environments in which they were familiar, motivated students to learn and develop their spatial thinking abilities. This study, conducted in four classrooms with just one computer each, particularly highlighted how the use of Google Earth can be motivating for students even when they are not the operator of the technology.

While there is a strong rationale for using GST as an engagement tool, such uses do not necessarily contribute to the improvement of students' geography learning. Indeed, as per the requirements of *Australian Curriculum: Geography*, the use of GST in geography classrooms must move beyond the level of engagement purposes towards facilitating students' capacity to develop an understanding of geographical concepts and skills and geographical thinking through the use of GST. Few research studies have so far sought to examine how teachers are using geospatial technologies for geography education in their classroom contexts. Indeed, much of the existing research has instead sought to examine the effectiveness of short-term GST interventions on student achievement (see, for example, Bodzin et al., 2014; Jadallah et al., 2017; Metoyer & Bednarz, 2017) Further research is needed to understand both if and how teachers are using GST for geography teaching as a natural and embedded part of their teaching repertoire outside of these intervention settings.

2.8 Teaching Change and Curriculum Innovation

Finally, this study was also concerned with the processes through which teachers' practices change in response to curriculum innovation, particularly regarding the adoption of technology. The use of geospatial technologies in geography teaching is a relatively new requirement for Australian teachers and research still indicates that few teachers have adopted GST in teaching (Baker & Langran, 2016). The inclusion of geospatial technologies within *Australian*

Curriculum: Geography, therefore, largely precedes teachers' adoption of the technologies in their geography teaching practices. This presents a clear dilemma: How can teachers be encouraged to change their practices to meet these new requirements?

A plethora of studies have investigated the personal characteristics of teachers and how these may influence whether teachers implement technology in their teaching. Gender (Volman & van Eck, 2001), teacher attitudes towards technology (Teo, 2008), teachers' computer self-efficacy (Peralta & Costata, 2007), pedagogical beliefs (Tondeur, van Braak, Ertmer & Ottenbreit-Leftwich, 2017) and length of teaching experience (Russell, O'Dwyer, Bebell & Tao, 2007) have been all been linked to teachers' use of technology in teaching. While these studies are useful in describing factors that may (or may not) contribute to teachers' inclusion of technology in their teaching, they do not specifically address how teachers can be encouraged and supported to change their practices or indeed take a lead in this area. Support for teachers in changing their practices will be of vital importance if geospatial technologies are to become widely used amongst geography teachers, as intended by the authors of the new curriculum.

2.8.1 Professional Learning

Perhaps unsurprisingly, the existing literature suggests that increased professional learning opportunities are required to encourage more teachers to use technology in their teaching (Albion, Tondeur, Forkosh-Baruch & Peeraer, 2015; Gravel, Mayall & York, 2016; Koh, Chai & Lim, 2017). This has also been a recurrent argument within the existing literature about teachers' use of GST. Numerous publications have reported on the outcomes of professional learning programs for teachers designed by researchers (Baker, Palmer & Kerski, 2009; Doering, Veletsianos, Scharber & Miller, 2009; Moore, Haviland, Moore & Tran, 2016). In these studies, professional learning was found to increase teachers' knowledge, confidence and capacity to use geospatial technologies in their teaching. Doering et al. (2009) found that a professional learning workshop about a GST application, GeoThentic, was successful in enhancing the knowledge and skills of 20 teachers who went on to use the technology in the classroom. Similarly, Doering, Koseoglu, Scharberg, Henricksong and Lanegrang's (2014) follow-up study also reported statistically significant positive changes in teachers' knowledge for teaching with GeoThentic and other geospatial technologies after a week-long professional learning intervention.

The research agenda for geospatial technology education developed by some of the field's leading researchers (Baker et al., 2015) speaks to a further need to design, deliver and evaluate professional learning opportunities with a view to identifying the efficacy of different professional learning models and methods. The authors argue that:

> … more and larger-scale efficacy studies are needed to determine the effectiveness of [professional learning] practices, including research to uncover how the efficacy of each practice varies across different content areas, teacher experience with GST, grade levels and student populations; and to examine how research-based [professional learning] in GST applied to disciplinary-based content areas can best impact student learning (Baker et al., 2015, p. 123).

Accordingly, research which enables further understanding of how teachers can be provided with opportunities to learn about geospatial technologies will be of critical importance during the implementation of the new GST curriculum requirements.

2.8.2 Peer Mentorship

Peer mentorship or peer coaching has been identified in some studies as a contributing factor in changing teachers' practices of using technology in the classroom (Ertmer, 1999; Glazer, Hannafin & Song, 2005; Zhao & Bryant, 2006). Glazer et al. (2005) examined the implementation of a "collaborative apprenticeship" (p. 57) model of peer-mentoring in a K-5 school setting. Collaborative apprenticeship, the authors described, consists of "reciprocal interactions between peer-teachers and teacher-leaders" (p. 59) in which less knowledgeable and confident teachers develop their skills and knowledge with support from their more experienced colleagues. The authors determined that the success of the collaborative apprenticeship model is contingent on teachers' shared planning and professional learning time, sustained levels of commitment to their learning, and varied levels of teacher experience to fulfil the roles of peer-teachers and teacher-leaders. Glazer et al.'s study nonetheless demonstrates the potential value of peer-mentoring in helping to shape and enhance teachers' technology practices. Baker et al.'s (2015) research agenda acknowledged that peer mentorship may be an effective method of supporting teachers to adopt geospatial technologies, however, further research is needed in this area to determine how peer mentoring may be enacted within a GST/geography learning context.

2.9 The Research Questions

This chapter identified a variety of issues related to teachers' adoption and use of geospatial technologies within geography teaching in secondary schools. Synthesis of previous research studies, many of which were conducted prior to the implementation of *Australian Curriculum: Geography* and recent increases in public access to geospatial information via mobile phones and other devices, illuminated further areas for research.

While Baker et al.'s (2015) articulation of a research agenda for geospatial technologies education research focused predominantly on encouraging researchers to seek further evidence of the impact of GST on student learning, the problem of low teacher adoption rates for GST persists (Baker & Langran, 2016). Thus, it is worthwhile examining many of these issues within the current curriculum climate.

The particular focus of this research was about investigating the experiences of early adopters of geospatial technologies for geography teaching in Australian secondary schools. Chapter Three introduces the concept of 'early adopters' and explains how this concept applies to those Australian teachers who are adopting GST in their geography teaching practices. This study, therefore, sought to address the 'research gaps' in the existing literature by examining the practices of these early adopters.

Studies conducted in the previous decade found that teachers have limited knowledge about how to use and implement geospatial technologies in their teaching (Bednarz & Bednarz, 2008; Wheeler et al., 2010). This study sought to determine whether this finding still rings true for today's early adopters. Therefore, the first research question was: RQ1. What are the characteristics of early adopters of geospatial technologies in geography teaching in Australian secondary schools?

Historically, barriers have existed to teachers' adoption of geospatial technologies, including limited technology access in classrooms, limited instructional time for teaching with GST and a lack of school administrative support (Beeson, 2006, Weigand, 2001). Few discipline-specific enablers of teachers' GST adoption have been previously identified. This study sought to understand how teachers' contexts (barriers and enablers) effect teachers' use of geospatial technologies in teaching and the extent to which previously identified barriers persist. The following research question was devised for this purpose: RQ2. How do context barriers and enablers influence early adopters' use of geospatial technologies in their geography teaching?

As argued by Baker et al. (2015) in their research agenda, "to date, we know little about how teachers enact a GST-integrated curriculum" (p. 124). Indeed, as many of the descriptions within the existing literature focus on teachers' use of GST in the context of researcher-led intervention studies, there have been few opportunities to demonstrate how teachers are adopting these technologies in their practices. This study, therefore, sought to better understand how teachers are using GST in their geography teaching outside of these intervention settings. Thus, the third research question was formulated: RQ3. How do early adopters utilise geospatial technologies to enhance their geography teaching?

This chapter also considered how teachers might be encouraged to change their teaching practices in response to the requirements to use GST in *Australian Curriculum: Geography*. In particular, it was identified that professional learning opportunities and peer mentorship programs have been found to be effective for enhancing teachers' technology adoption (Doering et al., 2014; Glazer et al., 2005; Gravel et al., 2016). Baker et al.'s (2015) research agenda acknowledged a need to further understand how professional learning opportunities can be presented to teachers, including which methods and models might be most effective. This study sought to address this research gap by exploring how early adopters can contribute to the professional learning of their peers and encourage the adoption of the geospatial technologies in their geography teaching. The fourth research question was designed to consider this issue: RQ4. In what ways do early adopters promote the diffusion of geospatial technologies amongst other geography teachers*?*

2.10 Chapter Conclusion

This chapter served as a review of the existing literature related to geospatial technology education and geography teaching. The review of the literature highlighted key themes within the GST-education literature, particularly the value of GST as a geography teaching tool (Metoyer & Bednarz, 2017; van der Schee et al., 2015) and the seemingly-persistent set of barriers to GST implementation experienced by teachers in schools (Akinyemi, 2016; Baker, 2015). The findings of this existing literature were used in this chapter to develop four key research questions designed to enrich understandings about teachers' adoption of GST in Australian geography classrooms. The focus of this study on Australian geography teachers is much needed. As reflected in the literature review, little has been written about Australian geography teachers' use of GST, particularly within the past decade.

The next chapter, Chapter Three, introduces the theoretical perspectives that informed this research: The Technological, Pedagogical and Content Knowledge (TPACK) framework (Mishra & Koehler, 2009) and the Diffusion of Innovations theory (Rogers, 2003). This chapter further contributes to defining the rationale for the study's research questions and its parameters.

Chapter 3

Theoretical Perspectives

3.1 Introduction

Two theoretical perspectives informed this research. First, the Technological, Pedagogical and Content Knowledge (TPACK) framework, first devised by Punya Mishra and Matthew Koehler in 2006, was used to analyse and explain early adopters' knowledge for using geospatial technologies in their geography teaching. Additionally, the TPACK framework, and subsequent amendments to the framework by later researchers, was used to tease out how the teaching contexts of the early adopters influenced their adoption decisions and to examine how early adopters' knowledge for teaching with GST is enacted in their practice. The TPACK framework particularly informed the research findings related to RQ1, RQ2, and RQ3.

Second, the Diffusion of Innovations (DOI) theory developed by Everett Rogers (2003) also guided this research in identifying those individuals who adopt innovative practices before the majority of their peers (that is, the early adopters) and how they contribute to the success or failure of an innovation through their communication of its benefits to their yet-to-adopt colleagues. Diffusion of Innovations theory, therefore, informed both the decision to focus this research on the early adopters of GST and the findings of RQ4.

3.2 Technological, Pedagogical and Content Knowledge (TPACK)

How teachers adopt, implement and make use of technologies in their teaching has been widely researched for many decades (McKnight et al., 2016). While a variety of theories have been offered to describe teachers' motivations for using technologies (Schulz, Isabwe & Reichert, 2015), their likelihood of adopting technologies (Teo, 2009) and how teachers can 'redefine' their teaching using technology (Puentedura, 2010), the Technological, Pedagogical and Content Knowledge (TPACK) theoretical framework remains widely-accepted and well-utilised for studying teaching with technology. While other frameworks, such as Puentedura's (2006) SAMR model, have yet to be sufficiently validated within education research (Hamilton, Rosenberg & Akcaoglu, 2016), the concerted efforts of many scholars have consistently demonstrated the validity and usefulness of Mishra and Koehler's (2006) TPACK framework for investigating technology-enhanced teaching (Cavanagh & Koehler, 2013; Chai, Koh & Tsai, 2011; Sahin, 2011; Schmidt et al., 2009). Indeed, a key strength of the TPACK framework is these on-going efforts to enhance the validity and reliability of the framework through regular amendments and adaptations to the framework (see, for example, Koehler & Mishra, 2009; Hunter, 2015; Porras-Hernández and Salinas-Amescua, 2013; Rosenberg & Koehler, 2015).

The Technological, Pedagogical and Content Knowledge framework extends Shulman's (1986) work in identifying and describing the "special knowledge" (Etkina, 2010, p. 020110-1) that teachers have for combining subject content (content knowledge) and general pedagogical strategies and approaches (pedagogical knowledge) during the act of teaching. Shulman named this special knowledge pedagogical content knowledge (PCK) and described it as:

> …embody[ing] the aspects of content most germane to its teachability. Within the category of pedagogical content knowledge I include, for the most regularly taught topics in one's subject areas, the most useful forms of representation of those ideas, the most powerful analogies, illustrations, examples, explanations, and demonstrations – in a word, the ways of representing and formulating the subject that make it comprehensible to others… [PCK] also includes an understanding of what makes the learning of specific concepts easy or difficult; the conceptions and preconceptions that students of different ages and backgrounds bring with them to the learning (Shulman, 1986, p. 9).

This "special amalgam of content and pedagogy that is uniquely the province of teachers" (Shulman, 1986, p. 8) forms the basis of the TPACK framework. Recognising the utility of the PCK concept, Mishra & Koehler (2006) identified an additional four domains of knowledge which they argued teachers act on during teaching with technologies: technology knowledge (TK); technological pedagogical knowledge (TPK); technological content knowledge (TCK) and technological, pedagogical and content knowledge (TPACK). Put simply by its architects, the development of the TPACK framework was "similar to the move made by Shulman in which he considered the relationship between content and pedagogy and labelled it pedagogical content knowledge… we introduce two new pairs and one new triad" (Mishra & Koehler, 2006, p. 1026). Figure 3.1 is a visual representation of Mishra and Koehler's (2006) articulation of the framework (then named TPCK). The authors later changed the name of the framework from TPCK to TPACK (Kohler & Mishra, 2009.

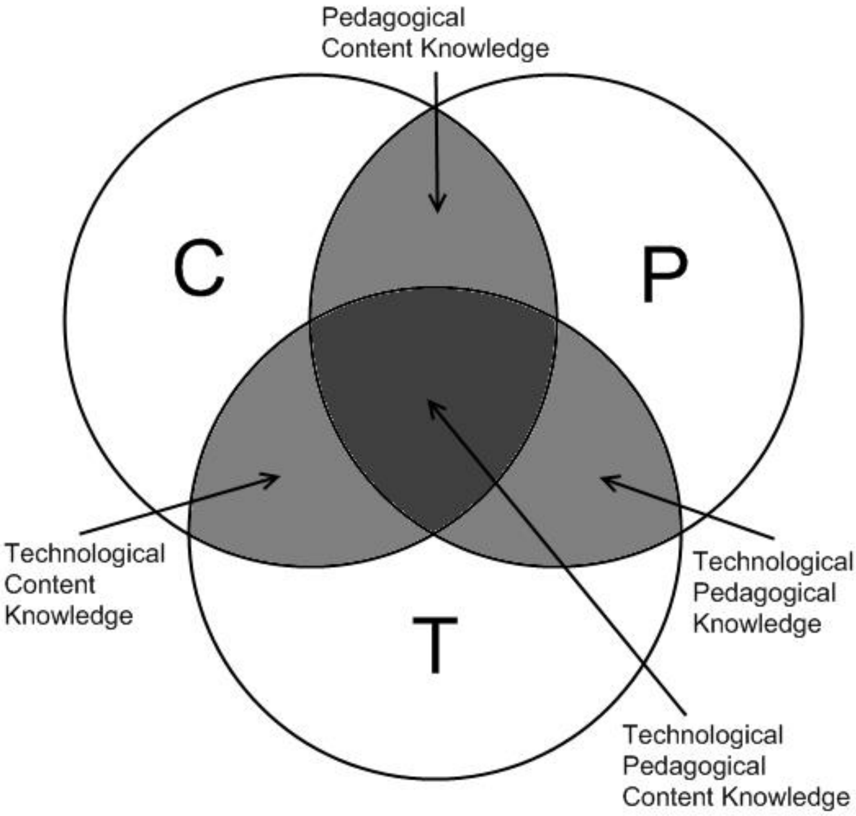


Figure 3.1. Mishra & Koehler's (2006) representation of TPCK.

3.2.1 TPACK Domains

The TPACK framework identifies seven domains of teacher knowledge that are acted upon when teachers use technology in their teaching.

Content knowledge (CK): Content knowledge refers to the subject matter that is to be taught by the teacher and learned by the students (Hunter, 2015). Content knowledge is specific to each subject discipline. Content knowledge for geography teaching could include knowledge of Earth's physical processes and its human populations, for example.

Pedagogical knowledge: Pedagogical knowledge includes knowledge of strategies and methods for teaching. Pedagogical knowledge incorporates knowledge of planning, assessment, behaviour management and student learning. Pedagogical knowledge also includes an "understanding of cognitive, social and developmental theories of learning and how they apply to students in a classroom" (Koehler & Mishra, 2009, p. 64).

Pedagogical content knowledge (PCK): Pedagogical content knowledge includes knowledge of the most appropriate and effective representations and examples of content, an understanding of those concepts and ideas that are difficult or easy for students to learn, and ways of identifying students' misconceptions and rectifying them. As Shulman identified, PCK is a special kind of knowledge that "goes beyond knowledge of subject matter per se to the dimension of subject knowledge *for teaching"* (1986, p. 9, original emphasis).

Technological content knowledge (TCK): Technological content knowledge refers to knowledge of how technology can vary the representation of content. Technology can change the way that students learn and understand specific content material (Schmidt et al., 2009). Technology provides both affordances and constraints to teaching content; while one technology might be appropriate for teaching a particular concept or idea, another may not. Teachers with developed TCK understand how to best represent their content with technology.

Technological pedagogical knowledge (TPK): Technological pedagogical knowledge concerns the knowledge of how teaching and learning is enhanced by the choice of particular technologies. TPK is an understanding of which particular technologies facilitate or constrain pedagogy. Teachers who exercise their TPK understand that using technology can alter the ways in which they teach (Schmidt et al., 2009).

Technological pedagogical [and] content knowledge (TPK/TPACK): TPCK/TPACK is the confluence of all variations of technological, pedagogical and content knowledge outlined in the framework. Teachers who exercise their TPACK have an extensive understanding of the complex interconnections and interdependences of each of the types of knowledge and select technologies, pedagogical strategies and subject content strategically to provide the best representations for student learning. TPACK, Koehler and Mishra (2009) contend, is present in all meaningful teaching with technology and includes:

> an understanding of the representation of concepts using technology, pedagogical techniques that use technologies in constructive ways to teach content, knowledge of what makes concepts difficult and easy to learn and how technology can help redress some of the problems that students face, knowledge of students' prior knowledge and theories of epistemology, and knowledge of how technologies can be used to build on existing knowledge to develop new epistemologies or strengthen old ones (p. 66).

It is important to acknowledge that the domains of the TPACK framework cannot, and should not, be considered in isolation from each other: that is, teachers access and draw upon knowledge from each of the domains concurrently during their teaching. The inter-connections and overlap between each of the knowledge types are represented in Figure 3.1. Nonetheless, for research purposes, each domain is a useful unit of analysis that can be used to gain a deeper understanding of teachers' knowledge for teaching with technology.

3.2.2 TPACK Framework Amendments/Adaptions

Amendments and adaptations to the TPACK framework have been regularly developed by the architects of TPACK and other interested researchers. The first of these amendments concerns the change of the name of the framework from TPCK to TPACK in 2009. While this change did not alter the nature of the knowledge domains, it did nonetheless allow the term to be more easily spoken and, thus, more widely recognised by academic audiences. In this study the term TPACK has been used to reflect the most recent iteration of the framework and to ensure consistency with the contemporary research literature in the field.

Most relevant to this study is the turn towards considering the relevance of context in the TPACK framework which is most evident within the TPACK literature published after 2009. In response to critiques that the framework failed to account for the influence of context on TPACK (Angeli & Valanides, 2009), Koehler and Mishra (2009) redesigned the TPACK image to reflect the place of context in the framework (Figure 3.2). Nonetheless, the importance of context within the framework has been regularly omitted in TPACK research studies. Kelly's (2010) review of TPACK literature, for example, found only one study that partially discussed the importance of context for TPACK (n = 16). This finding was supported by those of Rosenberg and Koehler (2015) who found that context was mentioned in only 36% of TPACK articles they reviewed (n = 193). While Rosenberg and Koehler (2015) maintain that "context has been described as central to the TPACK framework by its developers" (p. 186), the paucity of research studies acknowledging the place of context within the framework warrants further investigation.

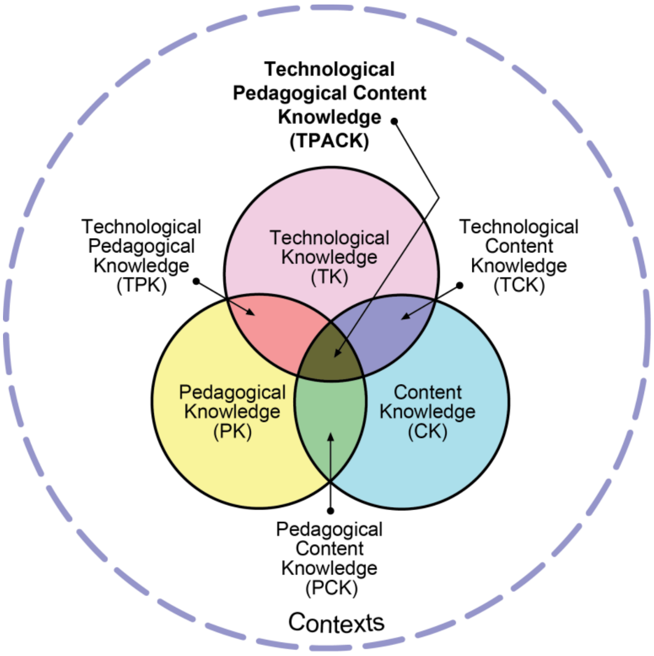


Figure 3.2. TPACK image identifying the place of context in the framework. Reproduced by permission of the publisher, © 2012 by tpack.org

Central to this study is the adaptation to the TPACK framework offered by Porras-Hernández and Salinas-Amescua (2013). In their study of the technology teaching practices of Mexican teachers, the authors determined that context conditions, such as student attributes, school characteristics, local and national policies and teachers' epistemologies of teaching were important factors that shaped teachers' TPACK. In their adapted framework, the authors conceived of three 'levels' of context – macro, meso and micro contexts – which could be used to explain the complexity of context and its influence on teachers' TPACK and teaching practices. Figure 3.3 is a visual representation of Porras-Hernández and Salinas-Amescua's (2013) levels of context.

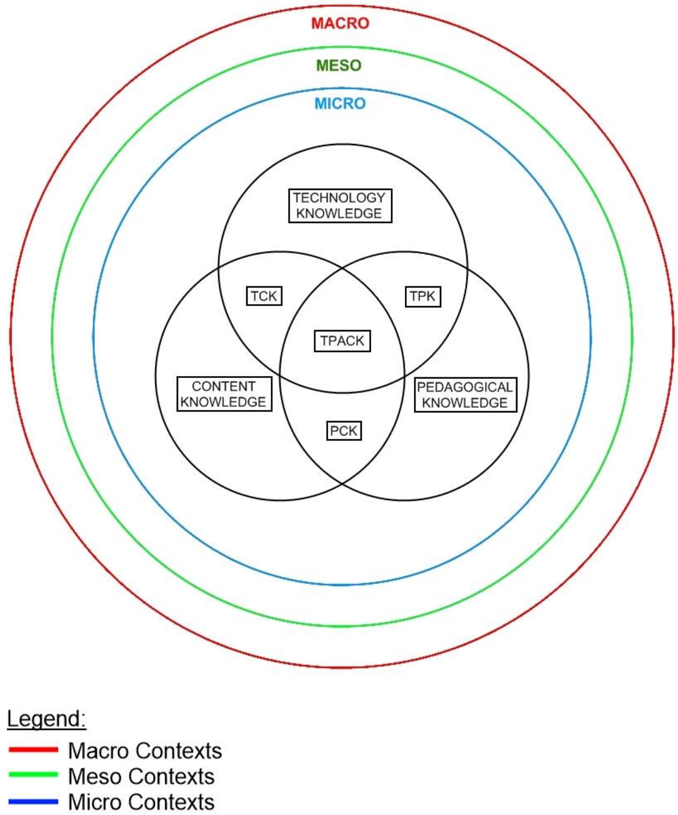


Figure 3.3. Levels of TPACK context (adapted from Porras-Hernández and Salinas-Amescua's (2013))

Porras-Hernández and Salinas-Amescua (2013) define these context levels accordingly:

Macro context conditions are "social, political, technological, and economic conditions. These include the rapid technological developments worldwide, which require constant learning, as well as national and global policies that, in the case of teacher technology integration, become especially relevant" (p. 228).

Meso context conditions are "social, cultural, political, organizational, and economic conditions established in the local community and the educational institution" (p. 288) and include the attitudes held and decisions made by school administrators, parents and the community about the implementation of technology in teaching.

Micro context conditions reflect the "in-class conditions for learning. These conditions may include available resources for learning activities, norms, and policies, as well as the expectations, beliefs, preferences, and goals of teachers and students as they interact" (p. 230).

3.2.3 TPACK and the Research Questions

Koehler & Mishra's (2009) TPACK framework and the subsequent adaptions to the framework made by Porras-Hernández and Salinas-Amescua (2013) were used in this research to guide the analysis of quantitative and qualitative data collected in response to RQ1, RQ2 and RQ3. Although Chapter Four will provide a more detailed explanation of the research methods used in this study, the relationship between the TPACK theoretical framework and the research questions are described here:

RQ1. What are the characteristics of early adopters of geospatial technologies in geography teaching in Australian secondary schools?

A TPACK framework-informed survey measured early adopters' technological, pedagogical and content knowledge for teaching geography with geospatial technologies. Early adopters' TPACK scores, in addition to collected demographic information, are used to identify the characteristics of early adopters.

RQ2. How do context barriers and enablers influence early adopters' use of geospatial technologies in geography teaching?

Porras-Hernández and Salinas-Amescua's (2013) conception of the 'levels' of context (micro, meso and macro) was utilised to examine the context conditions that early adopters identified as influencing their use of GST in geography teaching. Both data collected via the survey and semi-structured interviews with early adopters were analysed through the lens of Porras-Hernández and Salinas-Amescua's adapted TPACK framework.

RQ3. How do early adopters utilise geospatial technologies to enhance their geography teaching?

The TPACK framework was used to discern how early adopters utilise geospatial technologies in their geography teaching through the analysis of teachers' lesson and unit plans and students de-identified work samples (termed 'teaching artefacts' in this study).

3.3 Diffusion of Innovations

The second theoretical perspective that informed this research was drawn from the seminal work of Everett Rogers first published in 1962: the Diffusion of Innovations theory. In his book based on his PhD research, *Diffusion of Innovations,* Rogers explained how agricultural innovations were adopted in rural Iowa and theorised that the adoption of an innovation amongst a population (or social system) is fraught with difficulty, relying on the success of a process called 'innovation diffusion.' Diffusion is the mechanism by which an innovation is "communicated through certain channels over time among members of a social system" (Rogers, 2003, p. 5). Diffusion is about communication; individuals in a social system "create and share information with one another in order to reach a mutual understanding" (p. 5). Through communication between individuals, new ideas are spread and are either adopted or rejected by the individuals within the social system.

Rogers' theory outlines the qualities of an innovation that make it more likely to be successful. *Relative advantage* is the extent to which an innovation (for example, a new product) is perceived by individuals in the social system as being better than product that was previously used (Rogers, 2003). The greater the perceived relative advantage derived from the product, the more likely the product is to be adopted within the social system.

The level of *compatibility* of an innovation with the existing values and prior experiences of the social system also determines the likelihood of an innovation being adopted and the rate and/or speed in which the adoption takes place. Rogers (2003) argued that innovations that are perceived to be most compatible with the social systems' existing values and experiences are likely to diffuse faster than those innovations that are less compatible.

The extent to which an innovation is perceived as being easy or difficult to understand and use (*complexity*) is another factor influencing diffusion. Rogers (2003) determined that "the complexity of an innovation, as perceived by members of a social system, is negatively related to its rate of adoption" (p. 257); that is, the more difficult an innovation is to use, the slower the adoption of the innovation will be.

Trialability refers to the extent to which an innovation may be trialled or experimented with on a "limited basis" (Rogers, 2003, p. 258) before it must be fully adopted. In this instance, adopters 'try out' the innovation and reflect on the degree to which the innovation suits their needs. As Rogers (2003) argued, trialability is most relevant to earlier adopters of the innovation who ostensibly 'trial' the technology for their later adopting peers.

Finally, the degree to which the success of the innovation can be observed (*observability*) affects the extent and speed to which an innovation is adopted. Innovations whose results can be more easily observed are likely to diffuse faster than those innovations who results are difficult to observe.

In his research, Rogers (2003) found that the success of the diffusion of an innovation was strongly correlated with the extent to which more innovative individuals (whom he termed innovators and early adopters) positively perceived the relative advantage, compatibility, complexity, trialability and observability of the innovation and communicated that to their later adopting peers. While observing the process of diffusion, Rogers identified a series of “adopter categories” (2003, p. 279). These adopter categories can be used to describe the “innovativeness” (Rogers, 2003, p. 281) or the relative speed in which individuals in a social system adopt an innovation. Rogers’ five adopter categories are: Innovators, early adopters, early majority, late majority, and laggards (p. 281) and are represented in Figure 3.4.

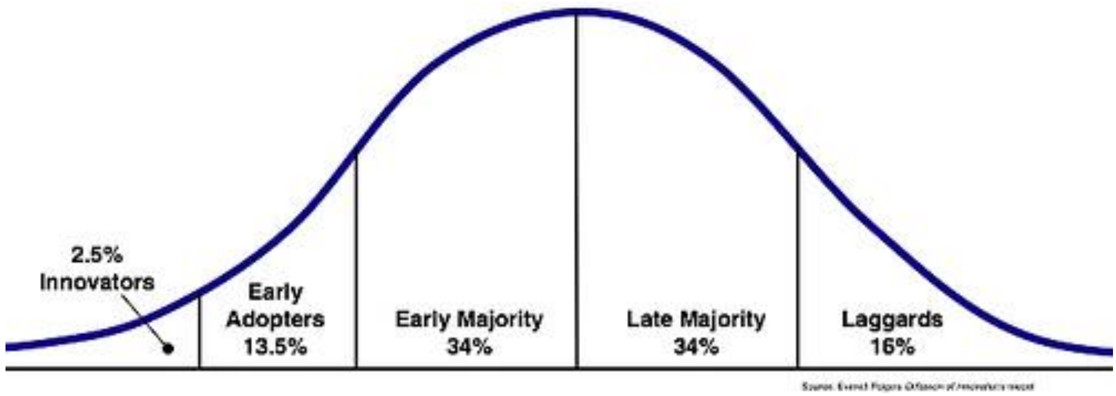


Figure 3.4. Rogers’ adoption curve including adopter categories.

In categorising individuals based on their innovativeness, Rogers identified the characteristics and values of the individuals in their respective groups and their prevalence within a social system.

Innovators, described by Rogers as the “first 2.5% of the individuals in a system to adopt an innovation” (2003, p. 280), are resilient to uncertainty about whether an innovation works or not and have the financial resources to sustain losses if the innovation proves unsuccessful.

Early adopters represent the next 13.5% of a social system, acting as opinion leaders by communicating their perceptions of the innovation to their later adopting peers. For Rogers (2003), the early adopter can be seen as the "individual to check with" (p. 283) or a "role model" (p. 283) for later adopters. Communication between the early adopter and later adopters works to "trigger the critical mass" (p. 283) necessary for widespread adoption. As described by Frattini, Bianchi, De Massis and Sikimic (2013), early adopters "constitute a source of information about the existence of [an] innovation, which propels purchase from prospective ensuing adopters" (p. 4). The perceptions and experiences of early adopters are critical in driving the diffusion of an innovation amongst a social system.

The *early majority* constitutes 34% of individuals within a social system. The early majority "adopt new ideas just before the average member of a system" (Rogers, 2003, p. 283) having learned of the benefits of adoption from the early adopters. While the early majority also communicate with their later adopting peers, the early majority do not act as "opinion leaders" (p. 283) as their early adopter peers do.

The *late majority* also accounts for 34% of individuals within a social system. For the late majority, adoption occurs as a result of peer pressure or as an economic necessity (Rogers, 2003). The late majority have reservations about adopting an innovation and, therefore, must be shown the benefits of the innovation by their earlier adopting peers.

Laggards constitute the last of the adopter categories. Accounting for the final 16% of adopters, laggards are "suspicious of innovations" (Rogers, 2003, p. 284) and often resistant to change. Laggards are highly risk averse. As laggards tend to have fewer resources than their more innovative peers, they must be entirely confident that the innovation works before they adopt. In some cases, laggards may never adopt an innovation.

3.3.1 Early Adopters

While each of the adopter categories identified by Rogers (2003) serves a specific function within the process of innovation diffusion, early adopters are particularly important in establishing the communication channels that work to encourage their peers to adopt an innovation. As such, the characteristics of early adopters and their role in the diffusion process has been the attention of considerable research, particularly within the context of business and marketing. Findings from business research offers a framework through which to understand how early adopters share their experiences with their later adopting peers and how they encourage their peers to take up an innovation. Additionally, the research also highlights the key characteristics of early adopters that may contribute to their ability or willingness to take up an innovation prior to most of their peers. In the present study, the role of early adopters in the diffusion of geospatial technologies amongst teachers and schools and the characteristics of early adopters of GST were explored. Research about early adopters in the business research context can, therefore, be usefully applied to the present analysis as a way of understanding the factors that enable the GST teaching of early adopters and the barriers for their non-adopting peers.

Any discussion of the types of adopters needs to acknowledge that the adopter categories identified by Rogers are ‘ideal types.’ As Rogers (1983, p. 247-248) argued:

> Ideal types are conceptualisations based on observations of reality and designed to make comparisons possible. The function of ideal types is to guide research efforts and to serve as a framework for the synthesis of research findings. Actually, there are no pronounced breaks in the innovativeness continuum between each of the five categories. Ideal types are not simply an average of all observations about an adopter category. Exceptions to the ideal types must be found. If no exceptions or deviations could be located, ideal types would not be necessary. Ideal types are based on abstractions from empirical cases and are intended as a guide for theoretical formulations and empirical investigations. They are not, however, a substitute for these investigations.

Subsequently, while Rogers delineated between adopter categories based on his observations during his research, in reality, the characteristics of early adopters may or may not match exactly to those described by Rogers. The implication of the ideal type for this research is that while many of the participants in this study share characteristics with the early adopters observed by Rogers, these characteristics may be more observable in some participants than others.

Evidence from Rogers (2003) and other studies within business research have provided a means of identifying early adopters based on a set of shared characteristics. A number of researchers agree that early adopters provide adoption leadership for their peers (Chan & Mishra, 1990; Chau & Hui, 1998; Lee, 2014). Early adopters identify the advantages, disadvantages and practicalities of adopting an innovation. Early adopters develop either a positive or a negative opinion of the innovation based on their experiences. Early adopters’ opinions have been found to be a critical factor in enticing later adopters to take up the innovation. Lee (2014) found that college students were motivated to adopt smartphone technology when they realised that their peers (early adopters) were already using smartphones and were expressing positive opinions about the technology. Chau and Hui (1998) also confirmed this characteristic in their analysis of early adopters of Windows 95. The authors determined that the early adopters “exhibited a high degree of opinion leadership” and that IT developers, in trying to encourage consumers to buy their product, “should focus their effort on ensuring that positive impression is obtained from [early adopters]” (pp. 228-29). Opinion leadership, or the degree to which early adopters develop a positive opinion of an innovation and express that opinion to their peers, is a key characteristic of the early adopter.

In providing opinion leadership, early adopters also play a critical role in reducing the uncertainty experienced by later adopters about the relative worth or benefits of an innovation. Compagni, Mele and Ravasi (2015) studied how early adopters drove the diffusion of robotic technologies for surgical procedures in Italian hospitals. The authors determined that early adopters significantly decrease the uncertainty of later adopters by sharing their experiences of implementing an innovation and by teaching their colleagues the skills needed to make the best use of the innovation. Similarly, Frattini et al. (2013), in their analysis of the diffusion of industrial product innovations, found that early adopters are critical to the success of innovation diffusion as they disseminate information about the innovation and communicate the potential of the innovation to the less confident buyer. Early adopters, in their appreciation of their peers’ uncertainty about an innovation, assist them to become more confident of the innovation’s virtues.

Higher levels of education and/or greater intelligence has also been identified as a characteristic of the early adopter. Dickerson and Gentry (1983) examined the demographic characteristics of adopters and non-adopters of the home computer. In their analysis, the authors found evidence to suggest that individuals with more education were more likely to be adopters. Jacobsen (1997), in her analysis of early adopters of technology for teaching, agreed with this contention and argued that early adopters demonstrate "greater intelligence" (p. 12) than later adopters. While the notion of "greater intelligence" could be perceived as subjective, there is nonetheless evidence to suggest that early adopters' higher levels of education make them more likely to appreciate the benefits of adopting an innovation.

Within the research, there is also evidence that early adopters are more likely to have had experiences with similar or like products prior to the innovation being diffused. Hirschman (1980) explored the concept of "consumer creativity" (p. 283) or the extent to which consumers can perceive how to problem solve with a new product. In her analysis, Hirschman determined that prior experiences with products from a similar product class to the new product increased the likelihood of that product being adopted. This contention is supported by Zaltman and Stiff (1973, cited in Dickerson & Gentry, 1983) who suggested that early adopters of a new product are likely to already be users of another product that can be used for the same purpose. Based on their experiences with a previous product, early adopters can envision the use/s of the innovation they are adopting.

Finally, there is some research evidence to indicate that younger people are more likely to be early adopters than older people. LeBay and Kinnear (1981), cited in Dickerson and Gentry (1983), argued that the median age of an early adopter of solar energy systems was 36-45 years. This argument is consistent with research conducted in the Netherlands by Diedren, van Meijl, Woltes and Bijack (2003). In their study of the diffusion of agricultural innovations amongst Dutch farmers, the authors found that older farmers were less likely to take up an innovation. Farmers who fell into the "innovator" category were also found to be younger still than early adopters. Accordingly, the age of the adopter may be associated with their "innovativeness" (Rogers, 2003, p. 267) or the rate at which they adopt an innovation.

3.3.2 Diffusion of Innovations Theory and the Research Questions

Rogers' (2003) Diffusion of Innovations theory (DOI) was used in this research as a way of identifying the focus of the study (i.e. early adopters) and for informing the analysis of qualitative data collected in response to RQ1 and RQ4. The relationship between the DOI theoretical framework, the research focus on early adopters and RQ1 and RQ4 is described here:

Research focus: Early adopters of geospatial technologies in geography teaching.

The existing research continues to identify the limited adoption of GST amongst geography teachers (Baker & Langran, 2016; Hong, 2017). Despite 20 years of research into the potential of GST in school contexts, the limited adoption of the technologies amongst teachers demonstrates that those using the technologies for teaching are 'early adopters.' Indeed, challenges related to recruiting participants for this study and the relatively small number of teachers who ultimately responded to the survey provided evidence that there remains a limited number of geography teachers using the technologies in their teaching in Australian school contexts. While identifying the number of Australian geography teachers using GST in their teaching was outside of the scope of this doctoral study, teachers' comments in the survey and interviews appeared to be consistent with findings from recent studies which identified limited teacher adoption.

RQ1. What are the characteristics of early adopters of geospatial technologies in geography teaching in Australian secondary schools?

Rogers’ classification of ‘early adopters’ and subsequent literature that further describes the characteristics of early adopters was used to further support and frame the discussion of the characteristics of early adopters of geospatial technologies in geography teaching.

RQ4. In what ways do early adopters promote the diffusion of geospatial technologies amongst other geography teachers?

The Diffusion of Innovations theory provides a framework for understanding how early adopters influence their peers through their communication of the relative advantage, compatibility, complexity, trialability and observability of an innovation. This framework was used to investigate how early adopters of geospatial technologies fulfil their role in the GST diffusion process through their communication with their teaching colleagues.

3.4 Chapter Conclusion

The research literature has consistently argued that the adoption of geospatial technologies in geography education has been limited (Baker & Langran, 2016) and that GST implementation in schools has been marred by barriers (Bednarz & Bednarz, 2008; Lam et al., 2009). Among these barriers, poor teacher knowledge for teaching with GST has been identified as a key obstacle to the presence of the technologies in schools (Demirci, 2009; Favier, 2011). In responding to these existing findings, this study sought to identify the knowledge of GST early adopters teaching in Australian secondary schools to determine if teacher knowledge remains a critical barrier to GST implementation. The inclusion of GST in *Australian Curriculum: Geography* necessitates widespread adoption of the technologies in Australian geography classrooms. As research evidence suggests adoption rates have been slow to increase over the past fifteen years (Baker & Langran, 2006; Kerski, 2000), there is a critical need for researchers to identify strategies to promote GST adoption.

To address the issues raised in the literature, two theoretical frameworks have been adopted in this study: The Technological, Pedagogical and Content Knowledge framework (Koehler & Mishra, 2009; Mishra & Koehler, 2006) (and Porras-Hernández and Salinas-Amescua (2013)'s adaption to the framework which recognised the importance of context on TPACK) and, the Diffusion of Innovations (Rogers, 2003) theory. The theoretical frameworks were used in this study to examine the practices of early adopters of GST and their role in the diffusion of GST in Australian secondary schools. The frameworks also informed the development of the research questions. In the next chapter, Chapter Four, the research methodology and the research methods that were used to collect this data are explored in greater depth and theory-informed analysis strategies are outlined.

Chapter 4

Research Methodology

4.1 Introduction

This chapter outlines the research methodology employed in this study, including the research design, data collection methods and the analytical approaches used to answer the research questions. Four research questions (RQs) frame this research:

RQ1. What are the characteristics of early adopters of geospatial technologies in geography teaching in Australian secondary schools?

RQ2. How do context barriers and enablers influence early adopters' use of geospatial technologies in their geography teaching?

RQ3. How do early adopters utilise geospatial technologies to enhance their geography teaching?

RQ4. In what ways do early adopters promote the diffusion of geospatial technologies amongst other geography teachers?

4.2 Research Design

4.2.1 Mixed Methods Research

A mixed-method design was employed in this research to study early adopters of geospatial technologies in geography teaching in Australian secondary schools. Mixed-method research involves the collection and analysis of quantitative and qualitative data within a single study. Morse and Niehaus (2009) define mixed-method research as being concerned with the "use of two (or more) research methods in a single study, when one (or more) of these methods is not complete in itself" (p. 9). Surveys, semi-structured interviews and teachers' lesson/unit plans and student work samples were the main sources of research data in this study.

The mixed-method research paradigm emerged from within the 'paradigm wars' that characterised debates within social research during the mid- 20th century. These 'wars' were the product of considerable tensions between quantitative and qualitative researchers who vehemently debated the merits of the methodological and philosophical orientations of the two research paradigms (Cameron & Miller, 2007). Although the paradigm wars worked to polarise many social researchers, debates in this period identified the inherent value of "multiple ways of seeing and hearing" (Greene, 2007, p.20). Mixed-methods research is a way of capitalising on the value of both quantitative and qualitative research methods. As argued by Teddlie and Tashakkori (2008, p. 10), mixed-methods researchers are free to engage in "methodological eclecticism"; that is, they can choose which research methods will most appropriately address the research question(s).

A mixed-methods research design was utilised to gather data about the knowledge, skills and confidence of the general population of early adopters of GST in geography teaching, as well as the context-specific experiences of some teachers in schools. This study sought to gain a better understanding of the capacity of early adopters to teach with GST in Australian secondary schools broadly and to identify how context conditions which influence how individual teachers practice specifically. Accordingly, a mixed-methods research design employing quantitative and qualitative data collection and analysis methods was suitably aligned with the research aims. The research design and methods utilised in this study also align with the quantitative (survey) and qualitative approaches (individual interviews) adopted by the field's leading researchers in the key monograph on geospatial technology use in geography education published in 2015 (see, Muñiz Solari, Demirci & van der Schee, 2015).

4.2.2 Explanatory Sequential Mixed-Methods Design

A quantitatively-driven explanatory sequential mixed-methods design (Creswell, 2015) has been employed in this study. An initial survey was distributed to Australian geography teachers to examine their knowledge for teaching geography with GST and how they use the technology in their teaching. The survey results were then supplemented and supported by semi-structured interviews with eight "good informants" (geography teachers) (Morse & Niehaus, 2009, p. 74) and examples of the teachers' lesson/unit plans, worksheets and de-identified student work samples ('teaching artefacts') were collected.

Morse and Niehaus (2009) emphasise the necessity of developing a clear theoretical drive to guide mixed-method research projects. Theoretical drive, according to the authors, is the "overall inductive or deductive direction of a research project" (p. 24). In a mixed-method study, they argue, one method must act as the 'driver' of the research while other research methods play a complementary or supplementary role in the conduct of the research. Decisions about the theoretical drive of the research must be informed by the research aims and questions.

The theoretical drive of this research can be described as QUAN → *qual* (Morse & Niehaus, 2009). The research is largely deductive with the quantitative findings from the survey used to frame subsequent qualitative data collection and analysis of semi-structured interview responses and teaching artefacts. The QUAN→ *qual* theoretical drive of this research is consistent with Creswell's (2015) explanatory sequential mixed-methods research design which is employed in the study (Figure 4.1).

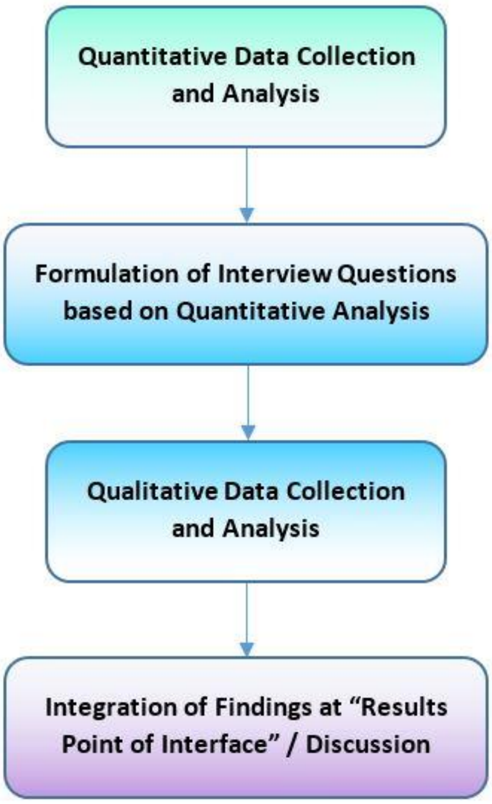


Figure 4.1. Explanatory sequential mixed-methods design

Some researchers argue that the methodological assumptions and philosophical orientations associated with quantitative and qualitative research are incongruent and incompatible within a single research study (Denzin & Lincoln, 1994; Povee & Roberts, 2015). This critique has been addressed many times by mixed-methods researchers, who maintain that mixing research methods yields greater depth of insight into the research problem than a single research method can provide (Venkatesh, Brown & Bala, 2013; Teddlie & Tashakkori, 2009). Nonetheless, such criticisms bring to attention the importance of researchers elucidating how separate datasets will be analysed and interpreted and their findings ultimately combined to address the research question(s) (Creswell, 2015). In developing this study, due diligence was paid to choosing research methods and data collection and analysis strategies that adhere to the methodological 'rules' of quantitative and qualitative research (Morse & Neihaus, 2009) and the study's overall QUAN→ *qual* theoretical drive.

4.3 Quantitative Research Phase

The initial quantitative research component of this study consisted of an online survey of Australian geography teachers who reported using geospatial technologies in their geography teaching (that is, those teachers considered early adopters of GST in the context of this study). The purpose of the survey was four-fold: (1) to collect demographic data about the teachers; (2) to measure the teachers' perceived technological, pedagogical and content knowledge (TPACK) and confidence for teaching geography with GST; (3) to identify common challenges and enablers for teachers' practice of teaching with GST; and (4), to determine ways in which the teachers use GST in their classroom.

4.3.1 Participants

Australian secondary school teachers of geography who use geospatial technologies in their teaching were recruited to participate in the online survey. Application to the Tasmanian Human Research Ethics Committee for ethical approval to approach teachers to participate in the research was granted on 6th November 2014 (Appendix A).

Two recruitment strategies were used to distribute the online survey to potential participants. First, permission was gained from the Tasmanian Department of Education and the Tasmanian Catholic Education Office to contact teachers in government and Catholic schools via email on 20th February 2015 and 8th July 2015, respectively. The web-link for the online survey was forwarded to geography teachers via their school principals.

While initially it was the intention to limit the conduct of the research to Tasmania as a form of "purposive sampling" (Palys, 2008, p. 697), the email recruitment strategy previously described did not yield a sufficient number of responses to allow for meaningful statistical analysis. As a result, a decision was made to expand the conduct of the research to allow for the participation of teachers in other areas of Australia. Contact was made with professional geography teaching associations in each state asking for their assistance in distributing the survey to their teacher members. The Geography Teachers' Association of New South Wales (GTANSW) and the Geography Teachers' Association of Victoria (GTAV) supported the research by distributing the survey web-link to their members via email (NSW) and through their newsletter (VIC).

The decision to expand the reach of the survey did raise an initial challenge. At the time of the research, *Australian Curriculum: Geography* had been implemented in most Australian states and territories, including Tasmania, the Australian Capital Territory, Northern Territory, Queensland and South Australia (ACARA, 2014). In New South Wales, teachers were still required to teach their existing curriculum framework *Human Society and Its Environment: Geography 7-10* (HSIE) syllabus, while in Victoria teachers were teaching geography within their previous state-based *AusVELS* curriculum. A review of the HSIE syllabus did not reveal any specific references to geospatial technologies. Review of the *AusVELS* curriculum revealed references to students using satellite imagery (a form of geospatial technology). While the original impetus for the study was the implementation of the *Australian Curriculum,* the geography teachers in NSW and Victorian schools who participated in the survey and implemented GST in this teaching nonetheless still represented the views of early adopters of GST in geography teaching. Therefore, it was decided that the different curriculum requirements within which the teachers work would be of limited consequence to the conduct of the research.

The survey was distributed on 20th July 2015 and, through the recruitment strategies described, 53 completed responses were received from early adopters of GST. Fifty-three was considered a sufficient number of responses to allow for sound statistical analysis (Hill, 1998) and was likely to be indicative of the population of teachers using geospatial technologies in the classroom (that is, those teachers who adopt the technology earlier than their peers). This sample size is consistent with the requirements for the types of statistical analysis conducted in this research (namely, descriptive statistics and *t*-tests). For such analyses, the “rule of thumb” for calculating sample size is n = >30 (Levine & Stephan, 2010; Rhiel & Chaffin, 1996; Sekaran, 2003). Indeed, de Winter (2013) argues that n = >2 can yield sufficiently robust findings for independent t-tests when researchers work with small sample sizes. Critically, decisions were made to refrain from conducting analyses that would prove less robust with a smaller sample size, such as factor analysis and regression (Comery & Lee, 1992; Green, 1991).

4.3.2 Research Instrument

The research instrument used in the quantitative research phase was an online survey of early adopters of geospatial technologies in geography teaching and consisted of 16 demographic multiple-choice questions, two Likert-scales of 28 items and seven items respectively, and four open-ended written response questions. The survey was adapted from a previously published research instrument, *The Survey of In-Service Teachers' Knowledge of Teaching and Technology* (Doering, Koseoglu, Scharber, Henrickson & Langeran, 2014). Doering et al.'s instrument, which consists of 28 items on a five-point Likert-scale, was used in the authors' study to examine 44 American middle school and high school teachers' knowledge for teaching geography with technologies. Used by the authors to evaluate the success of a professional learning workshop, the instrument was further adapted for this study to specifically measure Australian geography teachers' knowledge for teaching with geospatial technologies. The adapted instrument was given the name of the *Geospatial Technologies for Geography Education Survey* (*GST4GEOG*) to reflect the research focus on GST in geography education.

The design of the survey requires teachers to "self-report" their TPACK knowledge and confidence for teaching with GST. There are limitations associated with survey designs that rely on self-reported data. Most critical for this study, the "social desirability bias" or a tendency for participants to provide answers they deem more "socially acceptable" (Lavrakas, 2008), could have resulted in teachers' over-reporting their knowledge and confidence for teaching with GST in an attempt to appear more successful in their practice. In health research settings, Short et al. (2009) found differences between the self-report accuracy of men and women, while Sallis and Saelens (2000) argued that differences may be found in the way that individuals from different demographic, ethnic and cultural groups respond to self-report questionnaires and surveys. Despite these potential limitations, the self-report survey remains a consistently utilised research method for TPACK research studies (see, for example, Abbitt, 2011; Agyei & Voogt, 2011; Albion, Jamieson-Proctor & Finger, 2010; Koehler & Mishra, 2012). A self-report survey was, therefore, considered a justifiable method for collecting quantitative data for this study.

Doering et al.'s (2014) survey itself was derived from a previously published instrument; Schmidt et al.'s (2009) survey of the TPACK of 124 pre-service teachers. The survey developed by Schmidt and her colleagues is a widely accepted instrument, specifically designed by the authors to address the need for a reliable and well-validated means of measuring TPACK (Archambault & Barnett, 2010; Graham, 2011; Koehler, Shin & Mishra, 2012). This instrument was subject to a range of statistical and qualitative tests of the proposed items, including expert evaluation of content validity and factor analysis to determine internal consistency. In Doering et al.'s (2014) articulation of the instrument, 28 items were retained from Schmidt et al.'s work. Reliability analysis revealed high levels of item reliability with scores ranging from 0.82 to 0.92 during their pre-test and 0.76 to 0.94 for the post-test. As a review of existing TPACK literature revealed very few validated and reliable research instruments (Abbitt, 2011), the decision was made to adopt the Doering et al. 's instrument due to the high level of internal consistency reliability. Modifications were further made to the survey to reflect the focus on geospatial technologies (as opposed to generic ICT as measured in Doering et al.'s study). These modifications are reflected in Table 4.1.

Table 4.1

Modifications to Doering et al. (2014) in the Design of the GST4GEOG *Survey*

Doering et al. (2014) item	**Modified item in *GST4GEOG***
18. I know about technologies I can use for understanding and doing geography	18. I know about geospatial technologies I can use for understanding and doing geography
19. I can choose technologies that enhance the teaching approaches for a lesson	19. I can choose geospatial technologies that enhance the teaching approaches for a lesson
20. I can choose technologies that enhance students' learning for a lesson	20. I can choose geospatial technologies that enhance students' learning for a lesson
21. I think deeply about how technology could influence the teaching approaches I use in my classroom	21. I think deeply about how geospatial technology could influence the teaching approaches I use in my classroom
22. I am thinking critically about how to use technology in my classroom	22. I am thinking critically about how to use geospatial technology in my classroom
23. I can adapt the use of technologies to different teaching activities	23. I can adapt the use of geospatial technologies to different teaching activities
24. I can select technologies to use in my classroom that enhance what I teach, how I teach and what students learn	24. I can select geospatial technologies to use in my classroom that enhance what I teach, how I teach and what students learn
25. I can use strategies that combine content, technologies, and teaching approaches in my classroom	25. I can use strategies that combine content, geospatial technologies and teaching approaches in my classroom
26. I can provide leadership in helping others to coordinate the use of content, technologies and teaching approaches at my school and/or district	26. I can provide leadership in helping others to coordinate the use of content, geospatial technologies and teaching approaches at my school
27. I can choose technologies that enhance the content for a lesson	27. I can choose geospatial technologies that enhance the content for a lesson

28. I can teach lessons that appropriately combine geography, technologies and teaching approaches	28. I can teach lessons that appropriately combine geography, geospatial technologies and teaching approaches.

An additional seven Likert-scale items were constructed to collect data about teachers' confidence in using a range of geospatial technologies commonly used in education. These include: aerial photography, Google Earth, Google Maps, GIS, GPS, satellite photography and Spatial Genie. Participants were asked to describe their confidence on a five-point Likert-scale where 0 = not confident at all and 5 = very confident.

A further four open-ended written response questions were included in the *GST4GEOG* survey. Specifically, participants were asked to describe how they have used GST in their private lives (e.g. I can track my run using Strava) and how they have used them in the classroom for geography teaching (e.g. I used Google Earth to show the location of Africa). Participants were also asked to comment on their perceptions of the factors that influence their decisions to use GST in geography teaching and the nature of any training they have undertaken in relation to their use. The full text of the survey can be found in Appendix B.

4.3.3 Survey Trial

A limited trial was conducted to test the distribution strategy, coherence and intelligibility of the survey with a group of in-service secondary geography teachers. Three male teachers and two female teachers participated in the trial. The participants were aged between 25 and 60 and possessed between one and ten years of experience teaching secondary geography. All teachers had experience teaching Years 9 and 10, three teachers had experience teaching Years 7 and 8, while one teacher had experience teaching Year 11. Three teachers were employed in government schools, while the remaining two teachers were employed within the independent school sector. Only one of the teachers involved in the trial indicated that they had received any training in GST. The teachers' successful completion of the online survey indicated that the proposed distribution strategy was sound and that the questions could be understood by teachers of different genders, experience and school settings.

4.3.4 Quantitative Data Analysis

The online survey was closed to further responses in September, 2015, four months after its distribution. Reminder emails were sent to Tasmanian school principals and to geography teacher associations prior to the conclusion of the survey. On completion, 53 responses had been received that wholly addressed the TPACK Likert-scale items. Fifty-one of these responses also addressed the confidence Likert-scale items and provided written responses to the open-ended questions. Fifty-three responses were considered a sufficient sample to size to conduct the planned analyses (independent *t*-tests and descriptive statistics) and was a larger sample size than was obtained in Doering et al.'s (2014) original study utilising the survey instrument (n=44). This sample size is also larger than that of a recently published study by Hammond et al. (2018) which investigated the TPACK of American environmental science teachers who have adopted geospatial technologies in their classroom (n=4).

Quantitative data analysis was undertaken using IBM SPSS v. 22 software to enable conclusions to be drawn about teachers' knowledge and confidence in using GST to teach geography. In particular, descriptive statistics were generated, including scale means, item means, standard deviations and frequencies. Independent *t*-tests were also used to examine the relationship between demographic variables and TPACK responses. Levene's test for equality of variance (Levene, 1960) was performed during all *t*-tests and, in instances where equal variance was not apparent, the more robust Welch's *t*-test (Ruxton, 2006) was used to increase the power of the test.

Content analysis of written responses was also conducted to identify how participants use geospatial technologies in their classroom and the factors that influence their decisions to use GST in geography teaching. Content analysis is the "formal study of texts as a method of analysis" (Churchill, 2014, p. 255). To facilitate content analysis, codes were developed based on themes and patterns identified within the written responses. Coding, according to Babbie (2014), is the "process whereby raw data are transformed into standardised form suitable for machine processing and analysis" (p. 346). In particular, manifest codes (codes that represent concrete terms and phrases used by teachers in their written responses) were drawn out through a process of careful reading and re-reading of the written text and rigorous categorisation/grouping of the codes to identify themes and patterns in the data (Babbie, 2014; Miles & Huberman, 1994). Figures 4.2 and 4.3 are mind-maps of codes identified within the data that illustrate how the codes were grouped or categorised to identify common themes.

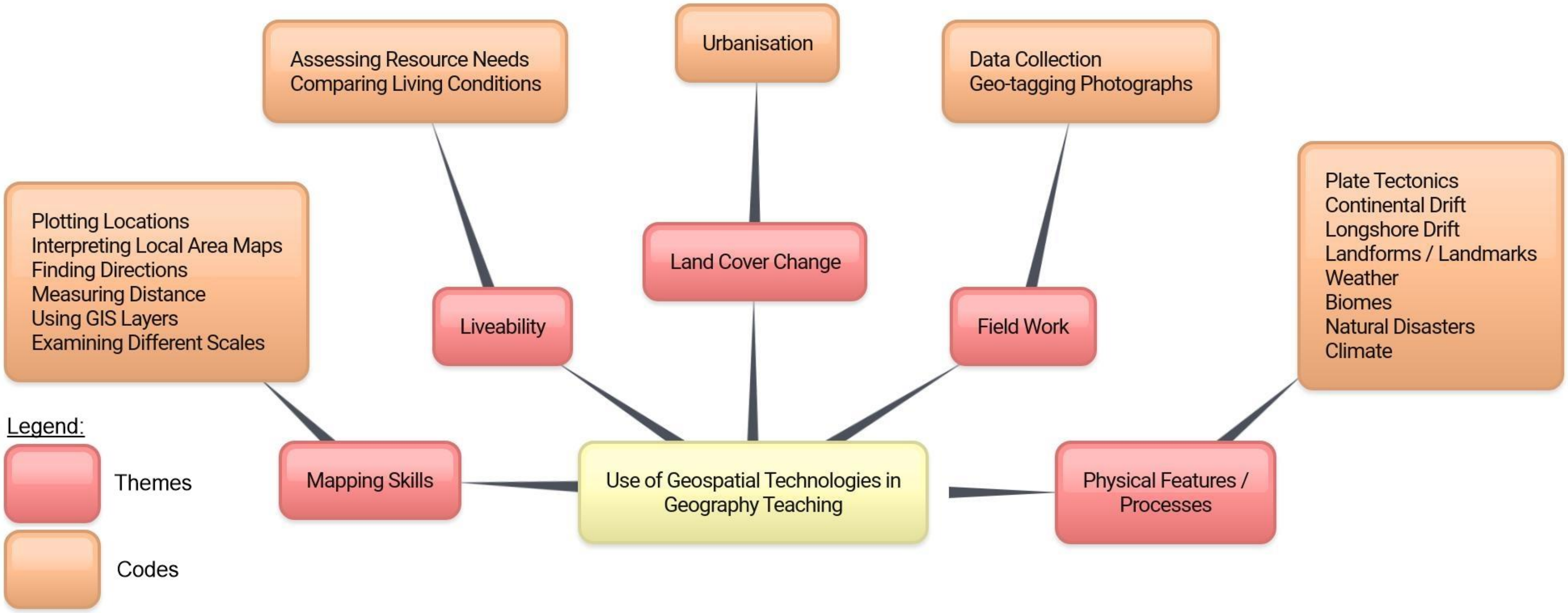


Figure 4.2. Mind-map of codes – Early adopters' use of GST in geography teaching.

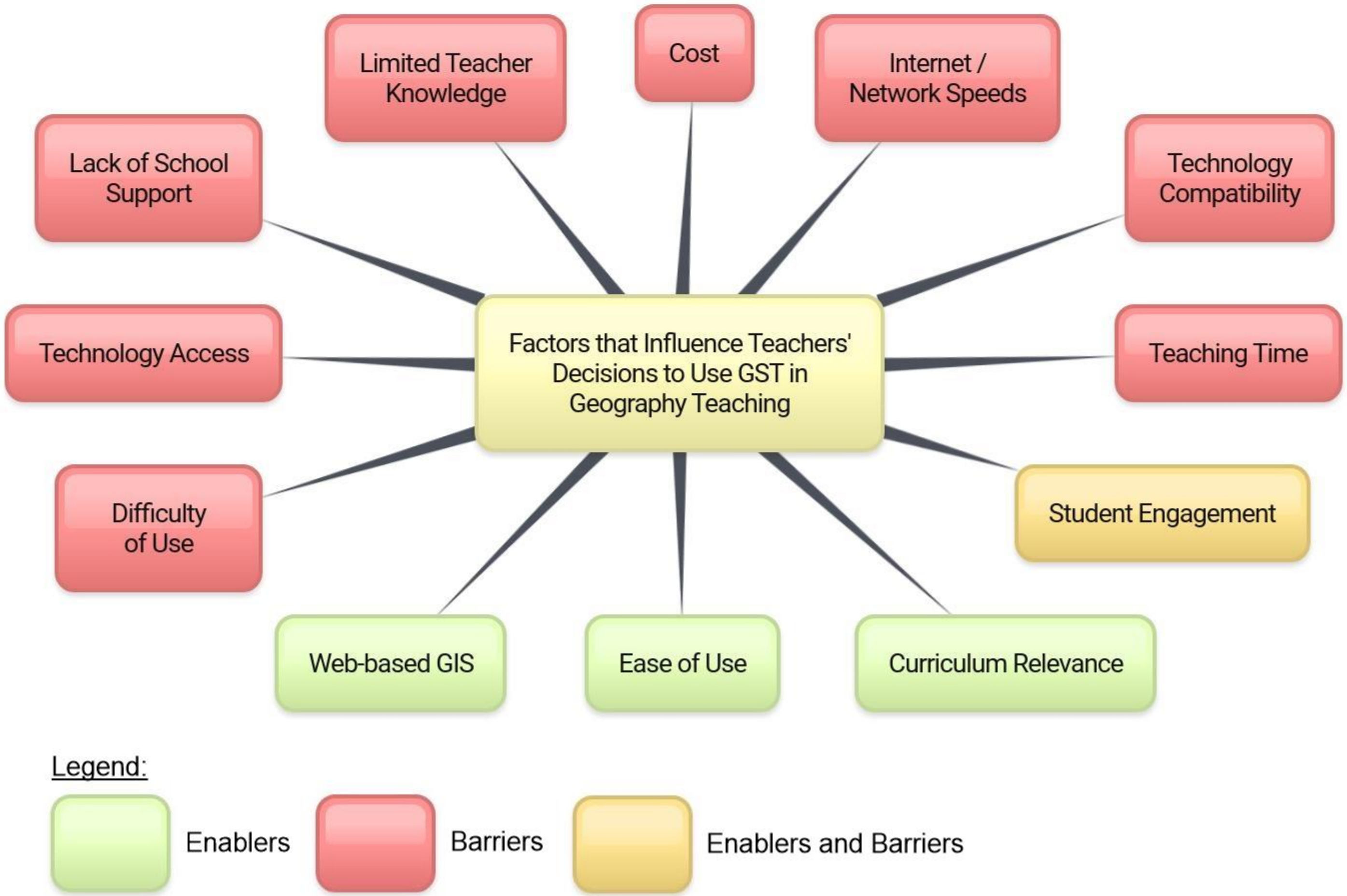


Figure 4.3. Mind-map of codes – Factors that influence early adopting teachers' decisions to use GST in geography teaching.

4.4 Qualitative Research Phase

On completing the survey, participants were asked to register their interest in participating in the qualitative research phase of this study. This phase consisted of semi-structured interviews with a small number of teachers who responded to the survey (and, thus, self-identified as early adopters of GST in geography teaching). The purpose of this phase of the study was to gain greater depth of insight into how teachers enact their technological, pedagogical and content knowledge when teaching with GST. Examples of lesson/unit plans, worksheets and de-identified student work samples were also collected for the purposes of exploring how the teachers used GST in their geography teaching.

Additionally, through the semi-structured interviews with the teachers, this study also sought to further understand the factors that influence teachers' decisions and capacities to implement GST. Specifically, the study provides qualitative evidence of the impact of context in influencing teachers' TPACK. Drawing on Porras-Hernández & Salinas-Amesuca's (2013) conception of the macro, meso and micro level contexts conditions that affect TPACK, the semi-structured interviews were used to gather evidence of how these context conditions shape early adopters' utilisation of GST. Semi-structured interviews with individual teachers were preferred over focus group interviews given the geographically dispersed nature of participants (in NSW, Victoria, South Australia and Tasmania). Additionally, as research suggests that more unique discussion points/findings can often be identified from individual interview data compared to focus group data (Heary & Hennessy, 2006), the decision to use semi-structured individual interviews is justified.

4.4.1 Participants

Efforts were made to ensure that teachers who participated in the interviews were from diverse backgrounds in terms of their age, experience and school sector. A total of 10 teachers initially registered their interest in participating in the semi-structured interview process. After contacting each teacher separately via email to confirm their participation, eight early adopters went on to agree to participate in the qualitative research phase. As 'theoretical saturation' is not a requirement of deductively-driven mixed-methods research (Morse & Niehaus, 2009), it was decided that interviews with eight teachers could provide sufficient insight into early adopters use of GST in geography teaching. This sample size is in keeping with the aims of qualitative research; qualitative research examines "particular actions and [their] meanings" (Smith, 1987, p. 176) as understood by individuals experiencing a specific phenomenon. In this study, eight teachers provided critical insights into their teaching practices and teaching contexts which allowed the researcher the opportunity to examine the influence of context on teachers' use of GST in geography teaching. The teachers who participated in this research phase had a diverse range of teaching experiences and education and had taught across all three school sectors (e.g. government, Catholic and independent school sectors).

4.4.2 Semi-structured Interviews

In accordance with the explanatory sequential mixed-methods research design employed in this study, the results of the analysis of quantitative data collected via the *GST4GEOG* survey were used to formulate the schedule of interview questions. Explanation and justification for these interview questions, with reference to the findings of the quantitative phase, are presented in Appendix C.

The semi-structured interviews were held via Skype in instances where the teachers were located in mainland Australia (six early adopters), while two interviews were held in the homes of the two Tasmanian teachers. Semi-structured interviews are “neither fully fixed nor fully free” (O’Leary, 2009, p.164); the researcher comes to the interview with some defined interview questions, however, both researcher and participant are free to explore topics and themes that emerge within their conversation. The nature of semi-structured interviewing means that the questions asked of each participant in this study often differed, reflecting the flow of the dialogue between the researcher and the participant. Using Skype for interview purposes was challenging at times: the bandwidth limitations of the mainland teachers in their homes or schools often resulted in video and audio ‘glitches.’ Such glitches necessitated teachers having to repeat some comments or were recorded as “inaudible” within the subsequent interview transcripts. Interviews were approximately one hour in duration for each teacher; however, two teachers agreed to speak with the researcher a second time to further unpack and describe the comments they made within their first interview.

Interviews were recorded using MP3 Skype Recorder, a software program which can record the audio from Skype sessions. Interviews which took place face-to-face in Tasmania were recorded using a hand-held recording device. The recordings were manually transcribed by the researcher to produce full transcripts of each interview. A sample of interview transcription is included in Appendix D.

4.4.3 Interview Data Analysis

After transcription, the interview transcripts were read multiple times and compared with the audio recordings to ensure accuracy. Interview transcripts were then imported into NVivo 10 qualitative data analysis software to facilitate thematic coding of the interview data. Thematic analysis was the strategy chosen for analysing the qualitative interview data because it is a method which is "independent of theory and epistemology, and can be applied *across* a range of theoretical and independent approaches" (Braun & Clarke, 2006, p. 78, original emphasis). The thematic analysis techniques advocated by Braun and Clarke (2006) were followed to ensure the integrity and quality of the research findings. These techniques, followed in the order described by Braun and Clarke (2006), included:

1. The researcher familiarising herself with the data through close and repeated reading of the transcripts, making notes and marking potential codes.
2. Generating initial codes by working systematically through the transcription, lending equal attention to each datum during the coding process.
3. Searching for overarching themes that connect individual codes and creating a visual representation (or mind-map) of the themes.
4. Reviewing and refining themes, ensuring that data within the themes "cohere together meaningfully" (p. 91), while also being clearly distinguishable from other themes.
5. Defining and naming the themes to identify the "essence of what each theme is about" (p. 92), ensuring that the themes contribute to answering the research questions.
6. Producing the report or 'writing up' the analysis using examples or extracts from the transcripts to illustrate the findings.

The mind-maps generated during the process of thematic analysis of interview data are included in Chapter Seven.

4.4.4 Analysis of Teaching Artefacts

Lesson/unit plans, worksheets and de-identified student work samples (or teaching artefacts) were also collected for the purpose of illustrating how early adopters utilise geospatial technologies in their geography teaching. To analyse this data, a procedure for interpreting the teaching artefacts was developed by the researcher. A framework was developed based on Anderson et al.'s (2001) revision of the *Taxonomy of Educational Objectives, Volume 1: Cognitive Domain* first published by Benjamin Bloom in 1956. Bloom's Taxonomy has been highly influential in shaping contemporary education practices, establishing a hierarchy of educational objectives which teachers can use in planning their teaching activities. In adopting Bloom's Taxonomy, teachers can provide students with more sophisticated and complex learning opportunities. Bloom's Taxonomy is a well-utilised framework for evaluating teaching and learning in contemporary education research (see, for example, Bijsterbosch, van der Schee & Kuiper, 2017; Hopson, Simms & Knezek, 2001). The use of this framework within this study is highly appropriate for analysing the emergent practices of GST early adopters and is consistent with recent efforts by Bijsterbosch, van der Schee and Kuiper (2017) to assess the quality of geography education in the Netherlands.

To facilitate the analysis, a visual representation of the framework was produced (Figure 4.4) and used as a rubric to evaluate the use of geospatial technologies in each artefact for enhancing geography teaching. The framework provides a clear articulation and description of what Bloom termed 'cognitive processes' (or thinking skills) with which students engage with when learning. The framework represents a hierarchy of cognitive processes with less complex cognitive processes or lower-order thinking skills (such as remembering and understanding) represented at the bottom of the hierarchy, while more complex and challenging cognitive processes or higher-order thinking skills (for example, evaluating and creating) constitute the top of the hierarchy. A grey arrow represents the order of the hierarchy from lower-order thinking skills to higher-order thinking skills. Lower-order thinking skills include recognising and recalling information from memory requiring students to simply identify or recite information. Higher-order thinking skills allow for planning, producing and generating a new product developed through synthesising and interpreting new learnings. It is notable that 'create' appears at the apex of the hierarchy, emphasising how high-quality learning activities enable critical and creative representations of students' learning.

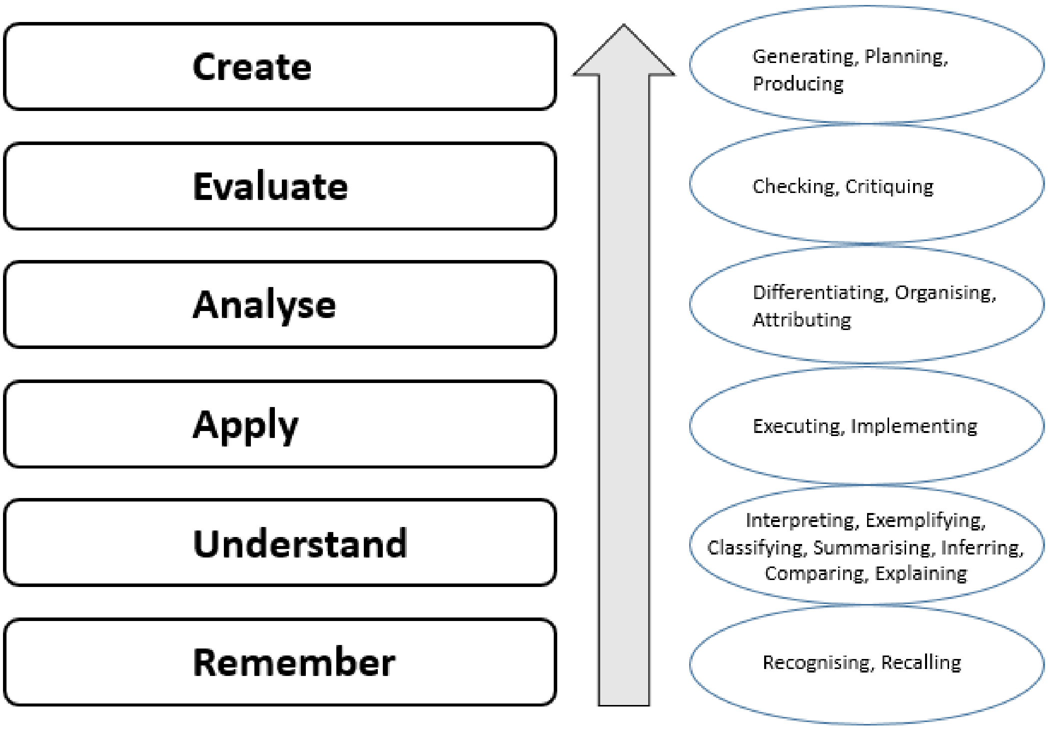


Figure 4.4. Teaching artefact interpretation framework.

4.5 Drawing Conclusions from QUAN → *qual* Research

One of the most challenging aspects of conducting mixed methods research is to identify how data collected within different research paradigms can be integrated or joined in such a way that the findings are meaningful and consistent with the methodological assumptions of the social science research paradigms. Mixed-methods researchers have long argued that, rather than being unaware of the ideological tensions at play within their research studies, mixed-methods researchers are highly cognisant of the "incompatibility problem" (Morse & Niehaus, 2009, p. 19) of mixing quantitative and qualitative research methods which are seemingly contradictory and inconsistent.

A number of mixed-methods research experts have made valid justifications for how mixed-methods research can be methodologically rigorous and systematically conducted. Creswell (2013), for example, argues that mixed-methods researchers "integrate", "merge" and "connect" their research findings, either in the data collection, analysis or interpretation stage (p. 208). While Creswell asserts that the merging of findings can happen at any stage of the research, mixed-methods researchers must clearly articulate how and when findings will be brought together.

Lending further support for mixed-methods research, Morse and Niehuas (2009) argue that quality can be derived from mixed-methods research through consistent and strict adherence to observing the methodological assumptions of both quantitative and qualitative research paradigms. Observing the methodological assumptions of both research paradigms ensures that mixed-methods research is conducted in a systematic, rigorous and credible way (Morse, 2003).

Although there are several approaches to conducting mixed-methods research, the explanatory sequential mixed-methods research design of this study dictates how, and at what stage of the study, the quantitative and qualitative research findings are drawn together. Consistent with Morse and Niehaus' (2009) description of studies employing a QUAN → *qual* theoretical drive, research findings are brought together at the "results point of interface" (p. 55); that is, the quantitative and qualitative components of the study are integrated within the discussions of the research findings in the forthcoming chapters.

4.5.1 The 'Results Point of Interface'

To explain and exemplify the process of merging findings at the 'results point of interface', a table has been produced which demonstrates the relationship between the research questions, the quantitative and qualitative data sources collected during this research and the data analysis techniques used to make meaning of the data (Table 4.2).

Each of the subsequent chapters of this thesis includes the presentation, analysis and discussion of quantitative and qualitative data which address each of the research questions. The merging of the data will therefore be achieved in Chapters Five, Six, Seven and Eight.

Table 4.2

Relationship between Research Questions, Data Collection and Analysis Techniques

Research Question (RQ)	**Data Collection**	**Data Analysis**
RQ1. What are the characteristics of early adopters of geospatial technologies in geography teaching in Australian schools?	*GST4GEOG* survey • Demographic questions • TPACK Likert-scale • Confidence Likert-scale Semi-structured interviews Teaching artefacts	Statistical analysis • Calculation of scale and item means, standard deviations and frequencies • Thematic analysis • Artefact analysis
RQ2. How do context barriers and enablers include early adopters' use of geospatial technologies in their geography teaching?	*GST4GEOG* survey • Open-ended questions Semi-structured interviews	• Content analysis • Calculation of frequencies • Thematic analysis
RQ3. How do early adopters utilise geospatial technologies to enhance their geography teaching?	Semi-structured interviews Teaching artefacts	• Thematic analysis • Artefact analysis
RQ4. In what ways do early adopters promote the diffusion of geospatial technologies amongst other geography teachers?	Semi-structured interviews	• Thematic analysis

4.6 Chapter Conclusion

A mixed-methods research design was employed in this study to examine the practices of early adopters of geospatial technologies in Australian secondary schools. A mixed-methods design was chosen to gather both depth and breadth in participants' responses (Doorenbos, 2014; Johsnon, Onwuegbuzie & Turner, 2007) enabling conclusions to be drawn about the early adopters of GST for teaching in Australian geography classrooms.

Surveys (*n*=54) and semi-structured interviews (*n*=8) were conducted with self-selected early adopters of GST and teaching artefacts were collected from some of these teachers (*n*=4). Analyses of the data included quantitative methods (descriptive statistics and *t*-tests) and qualitative methods (thematic and artefact analysis). The research design employed in this study was purposefully designed to address critiques within the existing literature about a lack of rigorous research on GST for education (Baker et al., 2015; Baker & Bednarz, 2003) through the careful consideration of alignment between research methodology, methods, questions and analysis strategies. The next chapter, Chapter Five, presents data, analysis and discussion of the quantitative data addressing research questions one, two and three.

Chapter 5

Early Adopters of GST for Geography Teaching

5.1 Introduction

This chapter presents findings from the analysis of the *Geospatial Technologies for Secondary Geography Education (GST4GEOG)* survey. In particular, data from the survey are analysed to provide insight into the characteristics of early adopters, the context conditions which they perceive to be influencing their decisions to adopt geospatial technologies, and the types of GST they use in the classroom. In doing so, this chapter provides some findings that address research questions (RQ) one, two and three.

5.2 Early Adopter Demographics

To address elements of RQ1, data was collected for five demographic variables to identify some of the characteristics of early adopters of GST in geography education. These variables are: gender; age; length of teaching experience; highest level of education; and, highest level of geography education.

5.2.1 Gender

Fifty-three teachers responded to the *Geospatial Technologies for Secondary Geography Education* survey. Of these teachers, 21 (38.6%) were male and 32 (59.2%) were female, representing a gender ratio of 1:1.5 (males to females). Recent studies of the Australian teacher workforce suggest a gender imbalance within the teaching profession. In 2013, 71.4% of teachers in Australian schools (primary and secondary) were women (New South Wales Department of Education and Training, 2013). Analysis from 2011 found that 58% of secondary school teachers were female (Australian Bureau of Statistics, 2011). Within the geography teaching profession, the gender disparity is greater. McKenzie, Weldon, Rowley, Murphy and McMillian, (2014), for example, found 61% of geography teachers were women. The distribution of teachers by gender within the survey aligns with these findings (approximately 60% female, 40% male).

5.2.2 Age

Although the age of the teachers did vary, the sample represented a reasonable distribution of teachers based on their age. The break-down of teachers' ages is as follows: three teachers (5.7%) were younger than 25 years of age; 11 (20.8%) teachers were aged between 25 and 30 years of age; 13 teachers (24.5%) were aged between 31 and 40; 10 teachers (18.9%) were aged between 41 and 50; 13 teachers (24.5%) were aged between 51 and 60; while a further three teachers (5.7%) were older than 60 years of age. The mean age for teachers in Australia is 42.9 years of age, with the proportion of teachers under 30 making up appropriately 15% of the total workforce and teachers over 50 accounting for approximately 37% (Freeman, Malley & Eveleigh, 2014). Within the sample, only 16 teachers (30.2%) were aged over 50, indicating fewer older teachers participated in the study than is reflected in the national teaching workforce.

5.2.3 Length of Geography Teaching Experience

Within the sample, the majority (62%) of teachers had taught geography for less than ten years. Given the average length of experience for secondary teachers in Australia is 17.3 years (McKenzie et al., 2014), there are fewer experienced teachers in the sample than is reflected in the general teaching population.

In the survey, teachers indicated their 'career stage' as determined by the Australian Institute for Teaching and School Leadership (AITSL, 2016) career classification system. AITSL identifies five career stages: Graduate (final year pre-service teacher to first year of teaching); Proficient (between one and five years of teaching experience); Highly Accomplished (five or more years of experience and some level of responsibility in a school); and, Lead (five or more years of experience and a position of responsibility in a school) (AITSL, 2016). Within the sample, 43.4% of teachers reported their career stage as Graduate or Proficient.

5.2.4 Highest Level of Education and Highest Level of Geography Education

As expected for a profession in which a tertiary degree is a prerequisite for professional registration and employment, all 53 teachers reported having a university-level qualification. A large proportion (62.2%, n = 33) also reported holding a postgraduate-level qualification (e.g. Postgraduate Diploma/Certificate, Master or Doctoral degree). While this finding appears to support the conclusion that teachers in the study have higher than average level of education (compared with the national teaching force in which only 34.68% of teachers hold a postgraduate level qualification (Freeman et al., 2014)), it is also possible that teachers with a post-Bachelor degree initial teacher education degree (e.g. a two-year Master of Teaching) reported this qualification as a postgraduate level degree. Under the Australian Qualification Framework (AQF) which regulates the quality of qualifications in Australia, an initial teacher education program (such as the Master of Teaching) is an equivalent level qualification (Level 9) to other taught and research Master's degree programs. Given the nature of the question asked, it is not possible to ascertain what proportion of teachers hold further postgraduate level qualifications obtained after their initial education course.

Only four teachers (7.5% of the sample) reported holding postgraduate-level qualifications in geography. Half the teachers (50.9%, *n* = 27) had Bachelor-level qualifications in geography. 41.5% of teachers (22 teachers) reported an undergraduate major in geography subjects. An additional 26 teachers, however, did not hold university-level qualifications in geography. Nine teachers reported not having studied geography since Year 10.

5.2.5 Summary of Demographic Variables

Both male and female teachers identified as early adopters of geospatial technologies in geography teaching. Early-GST adopting geography teachers in this study were highly educated with a large proportion holding postgraduate level qualifications. Few teachers, however, held postgraduate qualifications in geography, indicating that a postgraduate background in geography is not necessarily an indicator of early adopter status. Less experienced teachers (those with fewer than ten years' teaching experience) made up the bulk of the sample.

5.3 Early Adopters' TPACK for Teaching with GST

To further examine the characteristics of early adopters of GST, the participants' self-reported technological, pedagogical and content knowledge (TPACK) was explored. Means and standard deviations were calculated for scales (containing more than one item) and single items from the 27 TPACK Likert-scale items within the *GST4GEOG* survey.

5.3.1 TPACK Means and Standard Deviations

The 27 TPACK Likert-scale items were analysed to determine means and standard deviations for each of the seven TPACK domains; technology knowledge (TK), pedagogical knowledge (PK), content knowledge (CK), pedagogical content knowledge (PCK), technological pedagogical knowledge (TPK), technological content knowledge (TCK) and technological, pedagogical content knowledge (TPACK). In instances where more than one item sought to measure the domain, a scale score was calculated (for TK, CK, PCK and TCK). Single item means were calculated for the remaining domain (PCK, TCK and TPACK). Scale and item means and standard deviations are reported in Table 5.1.

Table 5.1

TPACK Scale and Item Means and Standard Deviations

TPACK Domain	Mean Score (scale)	Mean score (item)	Standard Deviation
TK	3.65		0.80
CK	4.04		0.62
PK	4.36		0.46
TPK	3.52		0.83
PCK		4.30	0.57
TCK		3.83	0.85
TPACK		3.83	0.87

N = 53

Pedagogical knowledge (PK) achieved the highest mean scale score among the participants (*M* = 4.36, *SD* = 0.46). Similarly, within the single items, pedagogical content knowledge (PCK) achieved the highest mean score *(M* = 4.30, *SD* = 0.57). This indicates that the teachers in this study were the most knowledgeable about pedagogy and the application of their pedagogical knowledge to geography teaching than about other aspects of teaching. The teachers, however, reported being less knowledgeable in their technology knowledge (*M* = 3.65, *SD* = 0.80), technological pedagogical knowledge (*M* = 3.52, *SD* = 0.83), technological content knowledge (*M* = 3.83, *SD* = 0.85) and technological, pedagogical and content knowledge (*M* = 3.83, *SD* = 0.87). Mean differences between each of the TPACK domains for all teachers are reported in Figure 5.1.

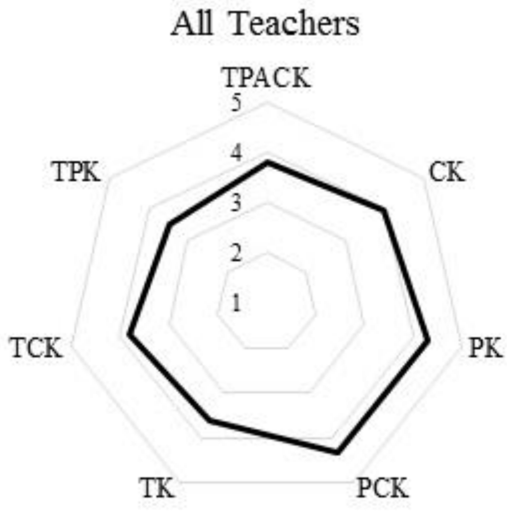


Figure 5.1. Mean scores for each TPACK domains for all teachers (*n* = 53)

The inclusion of technology had a noticeable effect on teachers' perceptions of their knowledge for teaching. While the teachers in this study generally perceived themselves to be quite knowledgeable about teaching geography (CK, PK, and PCK), they perceived themselves less knowledgeable about combining technology with geography content and pedagogy (TCK, TPK, and TPACK).

5.3.2 Variance in Teachers' TPACK

Demographic data, such as gender, age, length of geography teaching experience and highest level of geography education, were collected and examined to determine whether the demographic characteristics of early adopters in this study were related to their TPACK for teaching with GST. For this analysis, independent *t*-tests were conducted to examine the relationship between the demographic variables and each of the TPACK domains for teachers in this study.

Gender. Means and standard deviations for males and females in this study were calculated for each of the TPACK domains. To determine whether the differences in male and female responses were significant, independent *t*-tests were conducted. The *t*-tests revealed a statistically significant difference in scores for males (M = 4.28, SD = 0.42) and females (M =3.88, SD = .067) for content knowledge (*CK*): t (51) = 2.42, p = 0.02 (two-tailed); for technological content knowledge (TCK) (male M = 4.23, SD = 0.62, female M = 3.56, SD = 0.88): t (51) = 3.05, p = < 0.00 (two-tailed); for technological pedagogical knowledge (TPK) (male M = 3.82, SD = 0.64, female M = 3.32, SD = 0.88): t (51) = 2.27, p = 0.03 (two-tailed); and technological, pedagogical content knowledge (TPACK) (males M = 4.14, SD 0.57, female M = 3.62, SD = 0.97): Welch's t (50.52) = 2.43, p = 0.02 (two-tailed). There were no statistically significant differences found in this study between the means of males and females for PK, PCK, and TK. The independent *t*-tests, therefore, determined that men in this study reported being more knowledgeable than women in CK, TCK, TPK, and TPACK. Means, standard deviations and *t*-test results are presented in Table 5.2.

Table 5.2

Independent t-tests: Relationship between Gender and TPACK

Domain	**Mean (male)**	**SD (male)**	**Mean (female)**	**SD (female)**	**Mean difference**	**t-value**
CK	4.82	0.42	3.88	0.67	0.40	2.42**
PK	4.32	0.47	4.38	0.45	-0.08	-0.60
PCK	4.33	0.48	4.28	0.63	0.52	0.32
TK	3.85	0.64	3.21	0.88	0.34	1.52
TCK	4.23	0.62	3.56	0.88	0.67	3.05**
TPK	3.82	0.64	3.32	0.88	0.50	2.27**
TPACK	4.14	0.57	3.62	0.97	0.52	2.43**w

N = 53. ** = sig. w= Welch's *t*

Age. To assess whether the age of the early adopters in this study had a statistically significant relationship to their responses in each of the TPACK domains, means and standard deviations were calculated for teachers aged 40 years or younger and teachers aged 41 years or older. In this study, 27 teachers were aged 40 years or younger while 26 teachers were aged 41 years or older. Forty, therefore, represented a reasonable age in which to divide the sample for analysis. Independent *t*-tests were conducted for each of the TPACK domains. The *t*-tests identified statistically significant differences between the means of the two groups for pedagogical knowledge (PK) and pedagogical content knowledge (PCK). Younger teachers (M = 4.19, SD = 0.42) reported being less knowledgeable about PK than older teachers (M = 4.55, SD = 0.42): t (51) = -3.09, p = <0.00. In conducting the *t*-test for PCK, the Levene's test was not found to be significant and, therefore, equal variances between the groups was not assumed during the calculation. Instead, the more robust Welch's *t*-test was applied. Welch's *t*-test identified a statistical significance between two groups: Welch's t (48.35) = -3.18, p = <0.00. Younger teachers (M = 4.07, SD = 0.47) in this study reported being less knowledgeable in their PCK than older teachers (M = 4.54, SD = 0.58). Means, standard deviations and *t*-test results are reported in Table 5.3.

Table 5.3

Independent t-tests: Relationship between Age and TPACK

Construct	**Mean (< 40 years)**	**SD (< 40 years)**	**Mean (> 41 years)**	**SD (> 41 years)**	**Mean difference**	***t*-value**
CK	3.96	0.53	4.13	0.69	-0.16	-0.97
PK	4.19	0.42	4.55	0.42	-0.36	-3.09^{**}
PCK	4.07	0.47	4.54	0.58	-0.46	-3.18^{**w}
TK	3.76	0.66	3.52	0.92	0.25	1.18
TCK	3.74	0.81	3.92	0.89	-0.18	-0.78
TPK	3.36	0.76	3.69	0.87	-0.33	-1.50
TPACK	3.37	0.78	4.00	0.94	-0.33	-1.40

N = 53. ** = sig. ^{w}= Welch's *t*

Length of geography teaching experience. To determine whether the length of the teachers' experience in teaching geography had a statistically significant relationship to their self-reported TPACK, means and standard deviations were calculated for teachers in this study with ten years or less geography teaching experience and those with more than ten years' experience. Independent *t*-tests were then conducted to examine the relationship between the variables and TPACK. The *t*-tests identified that teachers in this study with ten years or less experience in teaching geography (M = 4.19, SD = 0.39) reported being less knowledgeable in their pedagogical knowledge (PK) than more experienced teachers (M = 4.66, SD = 0.40): t (51) = -4.26, p = <0.00. Additionally, the less experienced teachers (M = 4.03, SD = 0.47) also reported being less knowledgeable in their pedagogical content knowledge (PCK) than the more experienced teachers (M = 4.75, SD = 0.44). Means, standard deviations and *t*-test results are reported in Table 5.4.

Table 5.4

Independent t-tests: Relationship between Length of Geography Teaching Experience and TPACK

Construct	**Mean (< 10 years)**	**SD (< 10 years)**	**Mean (> 10 years)**	**SD (> 10 years)**	**Mean difference**	***t*-value**
CK	3.94	0.59	4.22	0.64	-0.28	-1.61
PK	4.19	0.39	4.66	0.40	-0.48	-4.26**
PCK	4.03	0.47	4.75	0.44	-0.72	-5.54**
TK	3.75	0.67	3.45	0.98	0.28	1.15^{w}
TCK	3.80	0.74	3.90	1.02	-0.11	-0.46
TPK	3.45	0.69	3.64	1.01	-0.20	-0.84
TPACK	3.76	0.71	3.95	1.10	-0.19	-0.78

N = 53. ** = sig. ^{w} = Welch's *t*

Highest level of geography education. To identify whether the early adopters' highest level of geography education had a statistically significant relationship with their self-reported TPACK, means and standard deviations were calculated for the teachers with secondary school (or equivalent) geography education levels and those with tertiary geography qualifications. Independent *t*-tests were then conducted to examine the difference between the two groups in this study. The independent *t*-tests revealed a significant difference between the means of those with a secondary school geography education and those teachers with tertiary geography qualifications. In this study, teachers with secondary school geography education (M = 3.67, SD = 0.71) reported being less knowledgeable about their geography content knowledge (CK) than those with tertiary qualifications (M = 4.29, SD = 0.38): t (51) =

-4.13, p = >0.00. Means, standard deviations and t-test results are reported in Table 5.5.

Table 5.5

Independent t-tests: Relationship between Highest Level of Geography Education and TPACK

Domain	**Mean (secondary)**	**SD (tertiary)**	**Mean (secondary)**	**SD (tertiary)**	**Mean difference**	***t*-value**
CK	3.67	0.71	4.29	0.38	-0.62	-4.13**
PK	4.30	0.42	4.41	0.48	-0.11	-0.87
PCK	4.09	0.62	4.44	0.50	-0.34	-2.19
TK	3.70	0.89	3.61	0.75	0.89	0.39
TCK	3.57	0.87	4.00	0.80	-0.43	-1.84
TPK	3.33	0.85	3.64	0.80	-0.31	-1.35
TPACK	3.62	0.92	3.97	0.82	-0.35	-1.44

N = 53. ** = sig.

5.3.3 Summary of Early Adopters' TPACK

Results from independent t-tests revealed that there was a relationship between gender and the teachers' knowledge of geography content (CK), their technological content knowledge (TCK), technological pedagogical knowledge (TPK) and technological, pedagogical and content knowledge (TPACK) for teachers in this study. In each instance, the men reported being more knowledgeable in these TPACK domains than the women. While some previous research has suggested that men have higher rates of acquiescence than women when self-reporting (Phillips & Segal, 1969; Ross & Mirowsky, 1984), further research with a larger sample size would be necessary to make a definite claim that this phenomenon accounted for the difference between the male and female scores in this study.

In this study, age was a variable that was found to be related to the early adopters' self-reported TPACK. The older teachers (that is, teachers aged 41 years or older) reported being more knowledgeable about their pedagogical knowledge (PK) and pedagogical content knowledge (PCK) than their younger counterparts. Results from independent *t*-tests also found that the teachers with more years of geography teaching experience reported being more knowledgeable about their PK and PCK than teachers with less geography teaching experience.

Similarly, there was a relationship between the teachers' reported geography content knowledge (CK) and the length of their geography teaching experience. Perhaps unsurprisingly, teachers in this study holding tertiary level qualifications in geography reported being more knowledgeable about geography content than those with secondary school levels of geography education.

The early adopters in this study collectively reported being the least knowledgeable in TPACK than all other domains within the framework. This finding suggests that support for teachers in developing their TPACK (the application of GST, pedagogy and content in teaching) should, be a consideration for teacher professional learning and initial teacher education.

5.4 Early Adopters' Confidence for Teaching with GST

To provide further analysis of the characteristics of early adopters of GST, teachers' self-reported confidence for teaching geography with geospatial technologies was examined. Data were collected using a five-point Likert-scale whereby early adopters indicated their confidence for teaching geography with some more commonly used geospatial technologies: aerial photography, Google Earth, Google Maps, Geographic Information Systems (GIS), Global Positioning System (GPS) and satellite imagery.

Descriptive statistics were calculated to identify means and standard deviations for each geospatial technology to determine how confident teachers reported being for teaching with each GST. Means and standard deviations are reported in Table 5.6.

Table 5.6

Confidence Means and Standard Deviations

GST – confidence for teaching	**Mean**	**Standard Deviation**
Aerial photography	3.98	1.07
Google Earth	4.20	0.87
Google Maps	4.31	0.79
Geographic Information Systems	2.37	1.38
Global Positioning System	3.29	1.28
Satellite Imagery	3.78	1.15

N = 51

5.4.1 Summary of Early Adopters' Confidence

Means and standard deviations reveal that teachers felt most confident for teaching geography with the Google mapping platforms – Google Earth (M = 4.20, SD = 0.87) and Google Maps (M = 4.31, SD = 0.79). The extent of teachers' confidence for teaching with the Google mapping platforms is most apparent when compared with their confidence for teaching with geographic information systems (GIS) (*M* = 2.37, *SD* = 1.38). Possible explanations for this could include:

- Google mapping platforms are popularly used by non-specialist audiences (i.e. 'lay people' without specialist expertise in geography, science or cartography). Teachers may have more familiarity with the operation of the Google mapping platforms as non-specialists.
- Google mapping platforms are available as free downloads whereas subscriptions to professional GIS software can be expensive.
- Google mapping platforms are embedded in many popular smart-phones (Android) or are available as downloadable applications (iPhone) making them easily accessible to smart-phone users.
- Teacher training opportunities may focus more on training teachers to use the Google mapping platforms than other professional GIS software.

5.5 The Influence of Context on Early Adopters' Use of GST

To examine the influence of context on early adopters' use of geospatial technologies in their geography teaching, qualitative data were collected by way of two open-ended questions which required teachers to provide written responses. These questions were: What factors influence your decisions about using geospatial technologies in the classroom? What would help or encourage you to use geospatial technologies in your teaching? Written responses were received from 51 participants.

A two-step data analysis strategy was used to identify the factors that the early adopters reported to be influencing their decisions about using geospatial technologies for teaching. Using the coding strategy described by Babbie (2014) and Miles and

Huberman (1994), as discussed in Chapter Four of this thesis, the following manifest codes were generated:

- Cost as barrier [to use of geospatial technologies in teaching];
- Technology access as barrier;
- Limited teacher knowledge as barrier;
- Teaching and planning time as barrier;
- Network/Internet speed as barrier;
- Curriculum/Task relevance;
- Student engagement;
- Technology compatibility as barrier (i.e. technology not functioning on different platforms – Android, iOS, Mac, Windows);
- Ease of use as enabler;
- Difficulty of use as barrier;
- Web-based GST as enabler; and
- [Lack of] school support as barrier.

Following the generation of the codes, a data transformation strategy was applied to determine the presence or absence of the codes in each of the written responses. The strategy, described by Driscoll, Appiah-Yeboah, Salib and Rupert (2007) and explained in Chapter Four, involved transforming the responses into a series of binary codes (0 = not present, 1 = present). The frequency in which each code appeared in the early adopters' responses were then calculated (Table 5.7). The presence of each code was recorded only once; that is, if a teacher mentioned cost as a barrier two or more times in their written response, the presence of the code was recorded only once.

Table 5.7

Factors that Influence Teachers' Use of Geospatial Technologies in Teaching

Factor	**Frequency**	**%**
Cost as barrier	17	33.3
Technology access as barrier	11	21.6
Limited teacher knowledge as barrier	11	21.6
Teaching and planning time as barrier	8	15.7
Network/Internet speed as barrier	6	11.8
Curriculum/Task relevance	6	9.8
Student engagement	5	9.8
Technology compatibility as barrier	4	7.8
Ease of use as enabler	4	7.8
Difficulty of use as barrier	3	5.9
Web-based GST as enabler	3	5.9
[Lack of] school support as barrier	2	3.9

N = 51

5.5.1 Summary of the Influence of Context

Within the early adopters' responses, cost was the most reported factor (reported in one-third of all responses) that influenced their decisions about using geospatial technologies in the classroom. In particular, the teachers perceived the cost of devices (e.g. computers, tablets etc.) and geospatial technology software to be a major barrier to their use of the technology in their teaching. Similarly, access to technology was the second most reported factor (21.6%), While this is consistent with previous Australian and international research (Kinniburgh, 2008; Rød, Larsen & Nilsen, 2010), it is an interesting result in light of increased access to technology in schools, the development of free geospatial technology applications and student mobile technology uptake.

Even amongst the early adopters of geospatial technologies, 11 teachers perceived their lack of knowledge for teaching with GST to be a major factor influencing their use of geospatial technologies. This finding is supported by the analysis of the TPACK Likert-scale responses in which teachers reported feeling less knowledgeable about the pedagogical application of geospatial technologies for teaching the geography curriculum (TPACK). Teachers' perceptions of their knowledge is clearly a critical deciding factor in their choice to use GST in the classroom.

Further consistent with previous research (Kerski, 2001), student engagement was found to be a factor that influenced teachers' decisions to use geospatial technologies for geography teaching. Student engagement was found to have both a positive and negative effect on teachers' decision-making. This is best exemplified by the following statements drawn from the written responses of two teachers:

Positive effect: "More importantly, I think it [geospatial technologies] will excite/engage the students to allow better learning outcomes."

Negative effect: "Students all have computers, and love to look around, they often get distracted and carried away with the technology in younger years."

This finding suggests that, while some teachers appreciate the value of geospatial technologies as a tool for engaging students in geography learning, other teachers are concerned about the impact of the technology on classroom management and student attention.

Only six teachers commented on the relevance of geospatial technologies to the geography curriculum and geography learning tasks as a factor influencing their decision making. Given the *Australian Curriculum's* emphasis on geospatial technologies, this is an important finding that raises questions about the extent to which the curriculum framework is influencing what is taught in schools. Furthermore, this finding may also suggest that teachers are uncertain of the relevance of geospatial technologies to the discipline of geography. Further emphasis on communicating to teachers the relevance of geospatial technologies to geography teaching may be needed to address this issue.

Mixed responses were received about the effect of the ease and/or difficulty of geospatial technology operation as a factor influencing teachers' decisions to use GST. Four teachers reported that the ease of operating free, web-based geospatial technology applications and platforms (e.g. Google Maps) was a factor that positively influenced their decisions to use geospatial technologies for teaching. While these comments are encouraging, another three teachers went on to report that the difficulty and complexity of operating geospatial technologies negatively impacted on their decisions to use GST in their geography teaching. Indeed, as prior research has established (Kerski, 2003), professional geographic information system (GIS) programs are quite complex for the lay-person to learn and operate. It may be that the three teachers reporting difficulty using GST are referring to the professional GIS programs that have been promoted in some professional publications (e.g. McInerney, 2002). Nonetheless, difficulty of use is still a clear barrier for some teachers wanting to use geospatial technologies for geography teaching.

While many of the barriers to geospatial technology use in the classroom have been reported in previous studies, it is important to note that these findings illustrate that the proliferation of free, web-based geospatial technology application suitable for lay-audiences (Such as Google Maps) provides some evidence for optimism about the increased use of GST for teaching.

5.6 Early Adopters Use of GST in Teaching

Qualitative data were further collected within the *GST4GEOG* survey to determine how early adopters are using geospatial technologies within their geography teaching. Fifty-one teachers provided a written response to an open-ended question: Can you describe a teaching activity you have conducted using geospatial technologies?

Within their responses, teachers indicated the types of geospatial technology applications and platforms that they have used in their classroom. Using the two-step data analysis strategy previously described, the types of geospatial technology applications and platforms that early adopters reported using in their teaching were identified. First, the responses were systematically reviewed by the researcher to identify the variety of GST that teachers reported using. These were: Google Earth, Google Maps, GPS devices, GIS, Google MyMaps, aerial photography and satellite imagery. Transforming the data into binary codes allowed for the frequencies to be calculated (Table 5.8). The presence of each code was recorded only once; that is, if a teacher mentioned using Google Maps for two separate teaching activities, the presence of the technology was recorded only once per written response.

Table 5.8

Types of Geospatial Technologies Used By Secondary Geography Teachers

Geospatial Technology	**No. of teachers**	**Percent of sample (%)**
Google Earth	38	74.5
Google Maps	14	27.5
GPS	3	5.9
GIS	3	5.9
Google MyMaps	2	3.9
Aerial and satellite photography	2	3.9

N=51

5.6.1 Summary of Early Adopters' Use of GST

A majority of teachers reported using Google Earth in their geography teaching (74.5%). The second most reported technology was Google Maps (27.5%). From these findings, it is clear that the Google mapping platforms are the most favoured geospatial technologies amongst secondary geography teachers in this study. As earlier postulated, the preference for Google mapping platforms amongst the teachers may be explained by the relative ease of access (free download) and ease of use of the technologies by non-specialist audiences. Similarly, teachers could hold the view that these non-specialist technologies may be more engaging or relevant to secondary school-aged children.

A further explanation for the popularity of the Google mapping platforms amongst the early adopters in this study could be their expressed confidence for teaching with the Google tools. Earlier in this chapter, teachers' confidence for teaching with geospatial technologies commonly used for educational purposes was examined. Teachers in this study reported feeling the most confident for teaching with the Google technologies than with other forms of GST – Google Earth (M= 4.20, *SD* = 0.87) and Google Maps (*M* = 4.31, *SD* = 0.79). Thus, teachers' level of confidence for teaching with a particular technology may be a factor in their use of the technology in their teaching.

Fewer teachers reported using GPS devices, geographic information systems and aerial and satellite photography in their teaching. Several explanations for this trend can be proposed. First, consistent with findings from previous research, the cost of GPS devices and subscriptions to geographic information system software may be a deterrent to teachers' use of the technology in the classroom (Yap et al., 2008). Second, teachers' expressed lack of confidence for teaching with geographic information systems (*M* = 2.37, *SD* = 1.38, on a five-point Likert-scale) which may account for why few teachers identified using GIS in teaching. Third, teachers may be uncertain about the application of GPS, GIS and aerial and satellite photography to geography teaching.

It is important to note that while many teachers provided multiple examples of how they have used geospatial technologies in the classroom, some teachers may have opted to simply provide one example in their written response and, therefore, did not report all of the geospatial technologies that they have used in the classroom. The means by which the data were collected (single-line response to an open-ended question) allowed only the identification of the technologies used in their geography teaching and not an in-depth analysis of the sophistication or complexity of how the technologies were used for teaching. Further research is needed to confirm the effectiveness or complexity of teachers' use of GST.

5.7 Contributions to Research Questions

Consistent with the explanatory sequential mixed-methods approach employed in this thesis, survey findings are merged and integrated (Creswell, 2013) with findings from the qualitative phase of the research within the proceeding chapters. Nonetheless, early adopters' responses to the *GST4GEOG* survey go some way towards responding to RQ1, RQ2 and RQ3.

5.7.1 Research Question One (RQ1)

RQ1. What are the characteristics of early adopters of geospatial technologies in geography teaching in Australian secondary schools?

Early adopters in this study are both male and female. The majority have less than 10 years' experience in geography teaching. A high proportion of early adopters have post-graduate level qualifications, however few of the early adopters possess advanced qualifications in geography.

The early adopters in this study reported generally high levels of technological, pedagogical and content knowledge (TPACK), especially pedagogical knowledge (PK) and pedagogical content knowledge (PCK). The early adopters reported lower knowledge in the 'technology-related' domains of TPACK (i.e. TPK, TCK and TPACK), although the mean score for each of these domains still achieved higher than a 'neutral' rating of 'neither agree nor disagree.' These results stand in contrast to those obtained by Doering et al. (2014) during their pre-test of teachers participating in their GST professional learning series. Prior to the professional learning, teachers reported relatively low levels of TPACK (M = 2.48, SD = 0.85) compared with early adopters in this study (M = 3.83, SD = 0.87). This is an important finding as the *GST4GEOG* survey was based on Doering et al.'s (2014) research instrument.

The early adopters in this study also report being quite confident in their use of some commonly used geospatial technologies (particularly the Google mapping platforms) but were less confident with GIS and GPS. This may be an important finding considering a host of 'intervention' style studies on the use of geospatial technologies in teaching have been conducted using professional GIS software (see Bodzin et al., 2014; Henry & Semple, 2012; Hong & Stonier, 2015, for example), rather than the less-complex Google mapping platforms which the early adopters reported being more confident in using.

5.7.2 Research Question Two (RQ2)

RQ2. How do context barriers and enablers influence early adopters' use of geospatial technologies in their geography teaching?

Consistent with previously published research, the context in which the early adopters practice was found to influence their decisions and/or capacities to adopt geospatial technologies in their geography teaching (Bednarz, 2003; Kulo & Bodzin, 2011; Wheeler et al., 2010). The cost of technology, including GIS software, GPS devices and computers, remains a key consideration for early adopters, with 33% of teachers identifying cost as a barrier to their use of GST. Similarly, access to such technologies was also considered a barrier by over 20% of the early adopters. Despite significant technology infrastructure investments in Australian schools (i.e. the Digital Education Revolution) and increased availability of geospatial technologies through smart phones/devices, cost and access to technology are still relevant barriers to teachers' adoption of GST in geography classrooms.

Also consistent with the findings of previous research, many of the teachers (n = 11, 21%) also perceived their own lack of knowledge about how to operate and use GST for teaching as a negative influence on their adoption decisions (Kerski, 2001; Wheeler et al., 2010). As suggested by Walshe (2017), teachers' lack of knowledge of GST may be attributable to limited professional learning opportunities in this area. The claim that there are few professional learning opportunities for teachers in GST can perhaps be further evidenced by the 60% of early adopters in this study who have not participated in such opportunities.

5.7.3 Research Question Three (RQ3)

RQ3. How do early adopters utilise geospatial technologies to enhance their geography teaching?

While the open-ended written response question asking teachers to describe a teaching activity using GST did not provide the early adopters with extensive scope to explain how they use the technologies to enhance their teaching, the data from the survey nonetheless revealed the teachers' strong preference for using the Google mapping platforms compared to another GST. Thirty-eight teachers (74%), for example, reported using Google Earth in teaching. This result aligns with the early adopters' articulation of their confidence for teaching with commonly used GST; the teachers reported being most confident with Google Maps (M = 4.31, SD = 0.79) and Google Earth (M = 4.20, SD = 0.87).

5.8 Chapter Conclusion

To address the research questions, this chapter identified the knowledge and confidence of Australian early adopters in teaching with GST (RQ1), the context conditions that influence early adopters' GST implementation (RQ2) and early adopters' practices of teaching with the technologies (RQ3). In this chapter, the relationship between demographics of early adopters of geospatial technologies, their self-reported TPACK and confidence for teaching with geospatial technologies and their responses to open-ended questions regarding how they use GST and the factors that influence their use of GST in the classroom were explored through statistical and qualitative analysis.

Early adopters in this study described being quite knowledgeable about GST and how the technologies can be used in geography teaching. Similarly, most of the adopters in this study were confident in their capacity to make use of the more accessible online mapping platforms, Google Earth and Google Maps. This finding stands in contrast to previous research suggesting that a critical barrier to the implementation of GST in school is a lack of teacher knowledge about using and teaching with GST (Akinyemi, 2016; Baker, 2015).

In the next chapter, Chapter Six, the knowledge and confidence of early adopters and the context conditions that influence their practice are further examined. Eight early adopters agreed to participate in the qualitative phase of this study. These teachers were interviewed about their professional contexts and their educational and teaching experiences. The early adopters' professional contexts and experiences are described in the next chapter. The 'thick, rich' description (Denzin, 1989) of these contexts draws further attention to the influence of context on early adopters' GST adoption and teaching practices.

Chapter 6

Early Adopters' Professional Contexts

6.1 Introduction

In Chapter Five, the *GST4GEOG* survey responses were analysed to address RQ1, RQ2 and RQ3. In the analysis, it was noted that the early adopters reported a range of factors about their teaching contexts that influence their GST adoption decisions. These included the cost of GST for school use, limitations on access to technology in the classroom and early adopters' own perceived deficits in their knowledge of how to operate and use geospatial technologies in geography teaching. This chapter acknowledges these findings, providing thick, rich descriptions of the professional contexts of the eight early adopters who participated in the qualitative phase of this research.

6.1.1 'Thick, Rich Descriptions'

Investigating the influence of context of teachers' adoption and use of geospatial technologies is a key aim of this research (RQ2.). It is, therefore, essential to provide detailed descriptions of each of the early adopters' contexts – their educational backgrounds, teaching experiences, self-reported knowledge and confidence for teaching with GST, their school settings and levels of access to technology for teaching – to enable meaning to be drawn from early adopters' interview remarks about the influence of context on their practice (i.e. the focus of Chapter Seven). Denzin (1989) defines thick description as "deep, dense, detailed accounts" (p. 83) that makes clear the context in which the studied phenomena occur.

In qualitative research, the use of such description is a widely accepted research practice to establish the credibility of a study's research findings (Creswell & Miller, 2000, p. 128). Creswell and Miller (2000) argue that rich descriptions "help readers to understand that the account is credible… [the descriptions] enable readers to make decisions about the applicability of the findings to other settings or similar contexts" (p. 129). Thick, rich descriptions of teachers' context enable conclusions to be drawn about the experiences that other teachers (i.e. those yet to adopt GST) may encounter when considering whether to use GST in their classroom.

6.2 Early Adopters' Professional Teaching Contexts

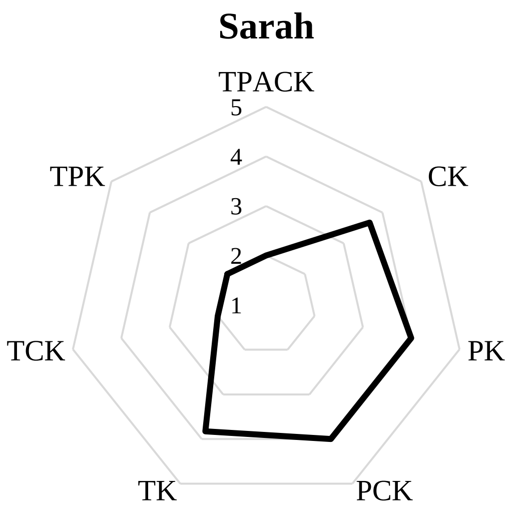
Given that context has been determined to have an impact on early adopters' choices to use GST in geography teaching, rich descriptions of each of the teachers' contexts are presented here. The early adopters who participated in the qualitative research phase are given the following pseudonyms: Sarah, Liam, Georgia, Melissa, Elizabeth, Russell, John and Eric.

6.2.1 Sarah

Sarah teaches Year 7 students at Redbrook High School in Tasmania. Sarah has two years of secondary geography teaching experience. At Redbrook High School, Sarah teaches Studies of Society and Environment (SOSE), an umbrella subject which includes history and geography. Sarah's position is a fixed-term part-time one-year contract in which she is responsible for teaching SOSE to Year 7 students.

Geography teaching experience and education background. Sarah does not possess a tertiary background in geography. In her survey responses, Sarah reported her highest level of geography education to be senior secondary school (Years 11-13). At university, Sarah completed a Bachelor of Arts majoring in Journalism and Political Science and spent some years in a public policy role before returning to complete a two-year postgraduate initial teacher education qualification in her mid-20's. In her interview, Sarah admitted her geography content knowledge is more limited than her knowledge of history content; "I'm learning on the job, somewhat."

TPACK for teaching with GST. Sarah's self-reported technological, pedagogical and content knowledge for teaching geography with geospatial technologies is presented in Figure 6.2.



CK	PK	PCK	TK	TCK	TPK	TPACK
3.67	4.00	4.00	3.83	2.00	2.00	2.00

Figure 6.1. Sarah's self-reported TPACK

Sarah's TPACK scores were lower than the means for the survey sample in each TPACK domain, except for technology knowledge (TK) (Sarah's TK *M* = 3.83; sample *M* = 3.65, *SD* = 0.80). This indicates that Sarah feels somewhat more knowledgeable about the general operation of GST than the average of the survey sample. Strikingly, however, Sarah reported lower scores for technological content knowledge (Sarah's TCK = 2.00; sample *M* = 3.83, *SD* = 0.85), technological pedagogical knowledge (Sarah's TPK *M* = 2.00; sample *M* = 3.52, *SD* = 0.83) and TPACK (Sarah's TPACK = 2.00, sample *M* = 3.83, *SD* = 0.87). This suggests that, although Sarah feels knowledgeable about using GST generally, she perceives greater deficits in her knowledge regarding the application of GST to geography and geography teaching.

Confidence for teaching with commonly-used GST. Sarah's responses to Likert-scale items describing her confidence for teaching with commonly used geospatial technologies for geography education is reported in Table 6.1. Consistent with the survey sample, Sarah reported feeling confident in teaching with the Google mapping platforms and aerial and satellite photography. Contrary to the mean score from the survey sample, Sarah also expressed confidence for teaching with professional geographic information systems (4.00). Despite Sarah's low score in the pedagogical application of GST knowledge component (1.80), Sarah nonetheless communicated a high degree of confidence in using all of the commonly-used GSTs included in the survey.

Table 6.1

Sarah's Reported Confidence for Teaching with Commonly-Used GST

GST	Score
Aerial photography	4.00
Google Earth	4.00
Google Maps	4.00
Geographic Information Systems (GIS)	4.00
Global Positioning System (GPS)	4.00
Satellite Imagery	4.00

School characteristics. Redbrook High School is a Government secondary school that educates students from Years 7 – 10. In 2015, student enrolments numbered 771 with indigenous students and students with a language background other than English accounting for 9% and 6% of the student population respectively (ACARA, 2016b).

The school's Index of Community Socio-Educational Advantage (ICSEA) value, a measure of the socio-educational backgrounds of the school's students developed by the Australian Curriculum and Assessment Authority (ACARA) for the purposes of making socio-educational comparisons between schools, is 971, below the national average of 1000 (ACARA, 2016). The distribution of the school's students based on ICSEA is represented in Table 6.2.

Table 6.2

Distribution of Redbrook High School Students Based on ICSEA

	Bottom quarter	**Middle quarters**		**Top quarter**
School Distribution	38%	31%	20%	11%
National Distribution	25%	25%	25%	25%

Source: ACARA, 2016b

According to Sarah, interest from families in enrolling their children at Redbrook High School is high and the school accepts a large percentage of its student cohort from families living outside of the local area. Additionally, the school receives interest from international students and Sarah, in addition to her teaching duties, is responsible for helping international students to enrol in the school.

National Assessment Program – Literacy and Numeracy (NAPLAN) results. The Australian standardised literacy and numeracy testing program (NAPLAN) scores reveal that students in Year 7 and Year 9 are underachieving on the tests (ACARA, 2015). Year 7 students at Redbrook High School achieved below the national average in reading, persuasive writing and numeracy and substantially below the average in spelling and grammar and punctuation. Likewise, students in Year 9 achieved below average scores in persuasive writing, spelling and grammar and punctuation. Students in Year 9 were close to the national average in reading and numeracy.

Teaching structure for geography. At Redbrook High School, geography and history are taught together within the umbrella subject of Studies of Society and

Environment (SOSE). In Year 7, Sarah's students attend three SOSE lessons a week over four school terms. Each term, Sarah's teaching focus changes – from history in Term One to geography in Term Two, for example. While history and geography are timetabled together under SOSE, students in Sarah's class receive mid-year and end-of-year assessment reports against the achievement standards for both *Australian Curriculum: History* and *Australian Curriculum: Geography*.

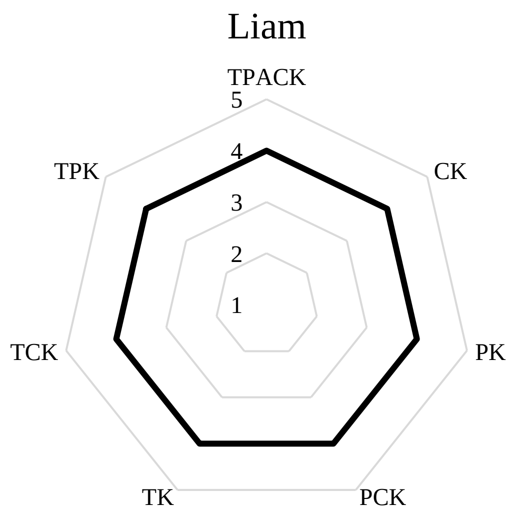
Technology access. Sarah stated that her school has six computer laboratory classrooms equipped with around 30 personal computers each or approximately 180 computers across the school. The school has recently implemented a Bring-Your-Own-Device (BYOD) program in which students in Years 9 and 10 are encouraged to bring their own laptops and iPad/tablets to school for use in class. The Year 7 students in Sarah's class did not participate in this program, although Sarah noted that some Year 7 students still brought their own devices to class. The school's BYOD program is not compulsory nor is there guidance from the school about which devices families should purchase for their children. The implications of this is that students bring a range of technologies with different capabilities to class. Sarah believes many students and their families are unable to afford the cost of BYOD technologies and, therefore, there are equity issues in the provision of technology at the school.

6.2.2 Liam

Liam teaches Year 9 and 10 students at Silverton College. Liam is responsible for teaching Year 7 and Year 9 Human Society and its Environment (HSIE), an umbrella subject for history and geography, and Year 12 Geography for the New South Wales High School Certificate (HSC). In addition to his teaching responsibilities, Liam is coordinator for Year 7, an administrative role for supporting student welfare, attendance and performance at the school.

Geography teaching experience and education background. Liam holds a Bachelor of Social Sciences with a major in Human Geography. His university degree enabled him to gain employment on graduation with a major telecommunications company using professional geographic information system software to make business decisions. After 13 years of employment in this role, Liam returned to university to study a one-year diploma program of initial teacher education to qualify as a secondary teacher of history, geography and English. Liam is one of two teachers at his school with a tertiary education in geography.

TPACK for teaching with GST. Liam's self-reported technological, pedagogical and content knowledge for teaching geography with geospatial technologies in presented in Figure 6.2.



CK	PK	PCK	TK	TCK	TPK	TPACK
4.00	4.00	4.00	4.00	4.00	4.00	4.00

Figure 6.2. Liam's self-reported TPACK.

Liam's scores were higher than the sample means in each TPACK domain other than content knowledge (Liam's CK *M* = 4.00; sample *M* = 4.04, *SD* = 0.62) and pedagogical knowledge (Liam's PK *M* = 4.00; sample *M* = 4.36, *SD* = 0.46). While Liam's pedagogical content knowledge score was lower than the sample mean (Liam's PCK = 4.00; sample *M* = 4.30, *SD* = 0.57), this was based on a single item and therefore cannot be reliably compared to the sample mean. These results emphasise Liam's perceptions of his strong knowledge of how geospatial technologies can be applied to geography and geography teaching (TK, TCK, TPK, TPACK).

Confidence for teaching with commonly-used GST. Liam's responses to the survey indicating his confidence for teaching with commonly-used geospatial technologies are reported in Table 6.3. Also consistent with the sample mean, Liam reported feeling confident in his use of the Google mapping platforms (4.00 for Google Earth and 5.00 for Google Maps) and aerial and satellite photography (5.00 for both technologies). Liam's confidence levels were consistently higher than the means of the sample. The contrast between Liam's confidence and the sample mean is most evident in Liam's score for geographic information systems (4.00 compared to sample mean of 2.37). Liam's confidence for teaching with GIS may be related to his professional experience using GIS as a business tool in his past employment.

Table 6.3

Liam's Reported Confidence for Teaching with Commonly-Used GST

GST	Score
Aerial photography	5.00
Google Earth	4.00
Google Maps	5.00
Geographic Information Systems	4.00
Global Positioning System	4.00
Satellite Imagery	5.00

*School characteristics***.** Silverton College is a co-educational Catholic school catering for students from Years 7-12. In 2015, student enrolments numbered 542 with indigenous students and students with a language background other than English accounting for 2% and 1 % respectively (ACARA, 2016b). The school's ICSEA value is 1018, slightly higher than the national average of 1000 (ACARA, 2016b).

The distribution of the school's students based on ICSEA is represented in Table 6.4.

Table 6.4

Distribution of Silverton College Students Based on ICSEA

	Bottom quarter	**Middle quarters**		**Top quarter**
School Distribution	21%	34%	29%	16%
National Distribution	25%	25%	25%	25%

Source: ACARA, 2016b

National Assessment Program – Literacy and Numeracy (NAPLAN) results. NAPLAN results for the 2015 school year reveal that Silverton College students performed close to the national average in all testing areas in Year 7. In Year 9, students performed close to the national average in all testing areas other than numeracy where the students performed below the national average.

Teaching structure for geography. At Silverton College, geography and history are taught within the compulsory HSIE umbrella subject from Years 7-10. In Years 11 and 12, geography is an elective subject. While all students in Years 7-10 undertake geography, the teaching structure for geography education differs across the year groups. In Year 7, students are taught geography in an interdisciplinary structure whereby one teacher alternates teaching history, geography and English across the school year. In Terms One and Two, English and geography are taught together, while in Terms Three and Four, history and English are taught together. Logistically, this results in lessons that focus on topics and resources that can be used to teach both subjects. As Liam explained, "when we're looking at different text types, we're going through the geography syllabus. They [students] might be doing a narrative about a World Heritage site, and then through that narrative we're teaching them the text type, the English stuff – the spelling, the grammar, the punctuation, the way to write, the way to deconstruct texts and stuff like that."

In Year 8, students are taught HSIE without English by the same teacher in two halves across the year. In Terms One and Two, students will learn history and in Terms Three and Four, the students will learn geography.

In Years 9 and 10, the school structures the teaching of geography and history to ensure that the classes are taught by specialist teachers (i.e. those with geography or history tertiary training). In the first half of the year, for example, Liam teaches geography to a class of students while a history-trained teacher teaches history to another class of students. In Term Three, Liam takes over teaching the history teacher's class in order to teach geography while the history teacher takes Liam's class from Terms One and Two. The rationale for this approach, Liam explained, is to attempt to "get as many students to have a geography and history trained teacher teach them those subjects… because I'm no good at history [and] some history teachers don't like teaching geography!"

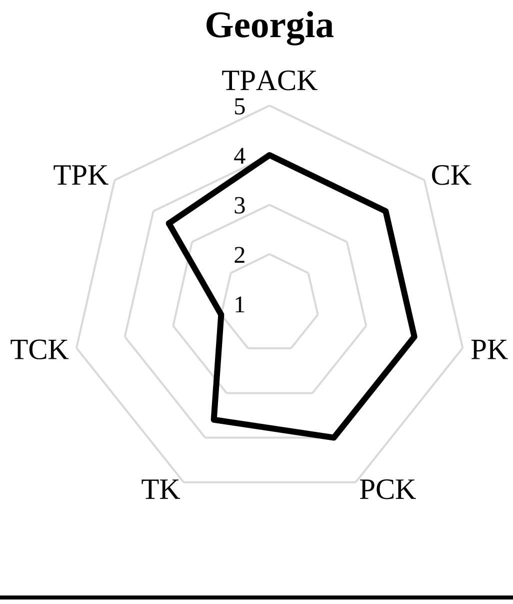
Technology access. Unlike Sarah's experiences, Liam believes computers are "easy to come by" in his school. Laptop computers are available in "every second classroom" which can be easily booked by teachers across the school. The school has recently updated its building facilities and included in the update was the provision of a number of "open learning rooms" which include 45 laptop computers and banks of iPads for student use. Additionally, Liam states the school's Wi-Fi network is "very robust" and very few times does he recall having an issue with the technology. The school is planning a move to a BYOD policy in the coming years and intends on using Google Apps for Education to support teaching and learning with student devices.

6.2.3 Georgia

Georgia has been teaching for five years. She is a trained secondary school teacher of English, history and geography. At Richmond School in Tasmania, where Georgia has taught since completing her postgraduate initial teacher education course, she is responsible for teaching Year 7 and Year 9 Humanities – history and geography – and English and Japanese.

Geography teaching experience and education background. As part of her Bachelor of Arts, Georgia studied Japanese, sociology and English, providing her with the prerequisites to study Studies of Society and Environment teaching method in her two-year graduate initial teacher education program. As part of her BA, Georgia undertook some units within her university's Faculty of Science which focused on Human Geography. Her undergraduate studies did not include any training for using professional geographic information systems, however.

TPACK for teaching with GST. Georgia's self-reported technological, pedagogical and content knowledge for teaching geography with geospatial technologies in presented in Figure 6.3.



CK	PK	PCK	TK	TCK	TPK	TPACK
4.00	4.00	4.00	3.6	2.00	3.6	4.00

Figure 6.3. Georgia's self-reported TPACK.

Georgia's TPACK scores are lower than the sample mean in each of the domains except for technological pedagogical knowledge (TPK) (Georgia's TPK M = 3.60; sample M = 3.52, SD = 0.83) and technological, pedagogical and content knowledge (TPACK) which was a single item within the Likert-scale questions. A clear difference is evident between Georgia's perceived TK, TPK and TPACK and Georgia's self-reported TCK. This result possibly indicates that, while Georgia feels reasonably knowledgeable about the use of GST pedagogically, she perceives herself to be less aware of the connections between GST and geography content.

Confidence for teaching with commonly used GST. Georgia's self-reported confidence for teaching geography with commonly used GST is presented in Table 6.5.

Table 6.5

Georgia's Reported Confidence for Teaching with Commonly Used GST

GST	**Score**
Aerial photography	4.00
Google Earth	5.00
Google Maps	5.00
Geographic Information Systems	1.00
Global Positioning System	2.00
Satellite Imagery	2.00

Consistent with the survey sample, Georgia feels highly confident for teaching geography with the Google mapping platforms, Google Earth and Google Maps (5.00 respectively). Georgia is also confident in her ability to teach using aerial photography. Strikingly, Georgia does not feel confident in using geographic information systems in the classroom. Georgia's score for GIS was lower than the sample mean (1.00, compared to sample mean of 2.37, *SD* = 1.38). GPS devices and satellite imagery are also technologies that Georgia feels less confident in using in teaching (2.00).

School characteristics. Richmond School is a co-educational independent school operating within the Uniting Church. The school provides education for students from Early Learning (pre-school) to Year 12. Across the school, student enrolments number 984. Four-percent of students speak a language other than English at home, while 1% of the student population identifies as Aboriginal or Torres Strait Islander (ACARA, 2016b).

The school's Index of Community Socio-Educational Advantage (ICSEA) is 1118, higher than the national average of 1000 (ACARA, 2016b). The distribution of the school's students based on ICSEA is represented in Table 6.6.

Table 6.6

Distribution of Richmond School students based on ICSEA

	Bottom quarter	**Middle quarters**		**Top quarter**
School Distribution	4%	13%	28%	54%
National Distribution	25%	25%	25%	25%

Source: ACARA, 2016b

*National Assessment Program – Literacy and Numeracy NAPLAN results***.** During the 2015 NAPLAN assessments, Richmond School students in Year 7 performed above the national average in all testing areas. In reading and persuasive writing, Year 7 students performed substantially above the national average. In Year 9, students scored substantially above the national average in reading, above the national average for persuasive writing, grammar and punctuation, and numeracy and close to the national average for spelling (ACARA, 2016b).

Teaching structure for geography. From Years 7 and 8, students at Richmond School are taught geography within the subject framework of 'Humanities.' At Richmond School, Humanities includes history, geography and civics and citizenship education. Humanities is a compulsory subject for all students in Years 7 and 8. In Years 9 and 10, students have choice in the disciplines they pursue in humanities education. Out of the three disciplines – history, geography, and civics and citizenship – students must elect to study two over the course of the school year. For example, students could choose to study history in the first half of the year and geography in the second half or not include geography in their studies at all. In Years 7 and 8, Humanities is timetabled for 6 hours per fortnight while students learn their chosen humanities disciplines for 10 hours per fortnight in Years 9 and 10. For Years 11 and 12, students can elect to study geography as one of their subjects for the Tasmanian Certificate of Education. Georgia stated, however, "not many [students] chose it."

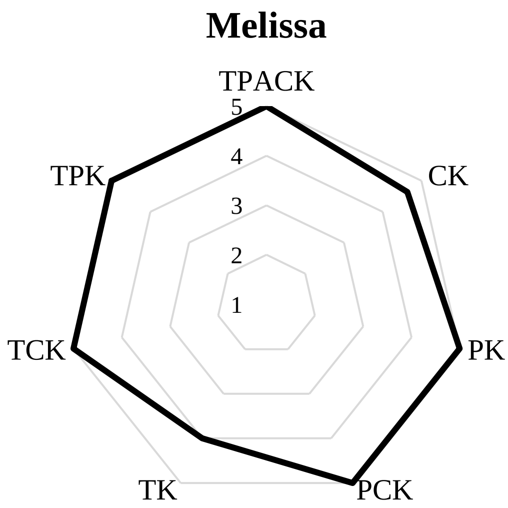
Technology access. Richmond school has an active BYOD policy from Years 8 -12 in which students and families select a device to purchase from a list approved by the school. In addition, desktop and laptop computers are widely available across the school with individual computer labs and banks of laptops available for student use in each year group from Years 7-12. All teachers in the school are provided with their own laptop computers, and televisions and/or interactive white boards are able to be connected to teacher laptops in every classroom. When asked about technology access in her school, Georgia did not perceive any difficulties in accessing computers.

6.2.4 Melissa

Melissa is a veteran teacher with over twenty years' experience teaching geography in secondary schools. At her current school, Colvin College, Melissa almost exclusively teaches geography to Year 7, 8, 9 and 12 students, although she also teaches history to one class. In addition to her teaching load, Melissa also coordinates the publication of the school magazine with her students.

Geography teaching experience and education background. Melissa completed her initial teacher education program to become a SOSE teacher. Prior to this, Melissa completed a Bachelor of Arts with a focus in history. Despite her history background, Melissa considers herself a strong geography educator having "learned a lot about teaching geography" over her twenty-year career. Starting her teaching career as a history specialist, Melissa's lengthy experience in geography teaching and her commitment to furthering her geography education has seen her become the most experienced and qualified teacher of geography at her school. As a result of her interest in geography content and her desire to gain a formal qualification in geography, Melissa studied a Master of Sustainability in 2013 which allowed her to pursue tertiary-level study in geography topics. Within her Master's degree, Melissa was able to study an elective course about geospatial technologies. While the course was useful in developing Melissa's confidence in operating geospatial technologies, the course was based on "using a PC and we [Colvin] are a Mac school! It was a program that we couldn't use!"

TPACK for teaching with GST. Melissa's self-reported TPACK for teaching geography with GST is presented in Figure 6.4.



CK	PK	PCK	TK	TCK	TPK	TPACK
4.64	5.00	5.00	4.00	5.00	5.00	5.00

Figure 6.4. Melissa's self-reported TPACK.

Melissa perceives that she has a high level of knowledge in each of the TPACK domains. Melissa's responses are higher than the mean scores for the survey responses in each domain. Melissa reported being least knowledgeable in her technology knowledge (TK) which suggests that, while she feels quite knowledgeable about how to embed geospatial technologies in her geography teaching, she feels less knowledgeable about the operation of these technologies more generally. Nonetheless, Melissa still reported higher TK than the sample mean (Melissa's *M* = 4.00; sample *M* = 3.65, *SD* = 0.80)

Confidence for teaching with commonly-used GST. Melissa's confidence for teaching with geospatial technologies commonly-used in education is represented in Table 6.7.

Table 6.7

Melissa's Reported Confidence for Teaching with Commonly-Used GST

GST	Score
Aerial photography	5.00
Google Earth	4.00
Google Maps	5.00
Geographic Information Systems	4.00
Global Positioning System	4.00
Satellite Imagery	5.00

Melissa reported high levels of confidence for teaching with all of the commonly used geospatial technologies for geography teaching. In particular, Melissa reported being very confident in teaching with aerial photography (5.00), Google Maps (5.00) and satellite imagery (5.00). Melissa reported being less confident in teaching with Google Earth (4.00) than with Google Maps. This indicates that, while both technologies are provided by Google, Melissa feels more confident in teaching with the simpler Google Maps user interface.

School characteristics. Colvin College is a Catholic school for girls in Year 7-12 located in a suburban area of Melbourne. In 2015, 1170 girls attended the school. Indigenous students made up 1% of the student population in 2015, while 49% of students possessed a language background other than English (ACARA, 2016b).

The school's Index of Community Socio-Educational Advantage (ICSEA) value is 1089, above the national average of 1000 (ACARA, 2016b). The distribution of students based on ICSEA is represented in Table 6.8.

Table 6.8

Distribution of Colvin College Students Based on ICSEA

	Bottom quarter	**Middle quarters**		**Top quarter**
School Distribution	6%	21%	34%	39%
National Distribution	25%	25%	25%	25%

Source: ACARA, 2016b

National Assessment Program – Literacy and Numeracy (NAPLAN) results.

Colvin College's NAPLAN results from 2015 reveal that students in Year 7 performed substantially above the national average in persuasive writing, grammar and spelling and punctuation and above the national average for numeracy and reading. In Year 9, students scored substantially above the national average in persuasive writing and above the national average for reading, spelling, grammar and punctuation. Year 9 students performed close to the national average in numeracy.

Teaching structure for geography. Although Colvin teaches girls from Years 7 -12, geography is only a compulsory subject for students in Years 7 and 8. Geography may be studied as an elective in Years 9 and 10. Melissa's perception is that geography is a popular elective amongst Years 9 and 10 students; there are four Year 9 classes and one Year 10 class. In Years 11 and 12, students can also elect to study geography within the Victorian Curriculum of Education. At Colvin College, two Year 11 classes and one Year 12 class study geography. Melissa perceives a positive trend towards increased post-compulsory enrolment in geography: “this year’s Year 11 cohort is bigger than we’ve had for years with the numbers. There is, I think, an understanding of the relevance of geography [among students].”

Inquiry-based learning and teaching is strongly promoted within the school. In Year 8, students at Melissa’s school participate in an interdisciplinary “city experience” study in which students explore issues related to social justice through the lens of geography. Visiting the city of Melbourne, students are required to independently research topics, such as homelessness, poverty, or the demography of crime. The students also undertake traditional geography fieldwork tasks, such as mapping and sketching and collecting, analysing and evaluating geographical data. This interdisciplinary inquiry approach to geography learning is “a really, really positive experience for them [students] that comes out of geography as well.”

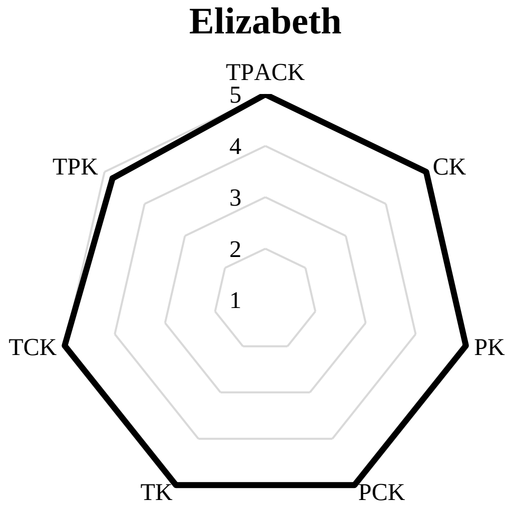
Technology access. Access to technology for teaching at Colvin College is readily available as a result of the College’s active technology provision policy. On enrolment, each girl at the school is provided with her own personal Apple MacBook laptop for use in class and at home for learning purposes. The use of students’ mobile technologies in the classroom (e.g. smartphones) is also supported and during the Year 8 “city experience”, students are encouraged to use applications, such as Google Maps, to facilitate their movements in and around the city. Melissa perceived no major challenges to teaching and learning stemming from access to technology.

6.2.5 Elizabeth

Elizabeth has been a teacher of geography in independent schools for ten years. Elizabeth has held her current position as geography teacher and Year 11 coordinator at Everton College in South Australia for the past eight years. In addition to teaching geography, Elizabeth is also responsible for teaching a research project subject at the school in which students devise and execute their own research into a topic of interest.

Geography teaching experience and education background. Elizabeth completed a Bachelor of Arts degree as a pathway towards a graduate level initial teacher education program. Elizabeth began her BA with majors in History and Mathematics but the need to “fill up” her BA with extra subjects led her to study geography. Elizabeth “fell in love with geography” because of inspiring lecturers and opportunities to undertake fieldwork within physical geography subjects. Elizabeth’s interest in geography led to her “dropping Maths because it was just too hard” and pursing an honours research project in geography. Having completed her degree in the 1990s, Elizabeth reported not having had any opportunity to use GIS or other geospatial technologies in her geography degree.

TPACK for teaching with GST. Elizabeth’s knowledge for teaching with geospatial technologies is represented in Figure 6.5.



CK	PK	PCK	TK	TCK	TPK	TPACK
5.00	5.00	5.00	5.00	5.00	4.80	5.00

Figure 6.5. Elizabeth's self-reported TPACK.

Elizabeth's mean scores in each of the TPACK domains are higher than the means for the survey sample. Elizabeth's responses to the scale and single items within the *GST4GEOG* survey demonstrate that Elizabeth feels highly knowledgeable for embedding geospatial technologies within her geography teaching.

Confidence for teaching with commonly-used GST. Elizabeth's confidence for teaching with GST commonly-used in geography education is reported in Table 6.9. Elizabeth's responses illustrate her high level of confidence for teaching with commonly-used GST. Elizabeth reported being more confident for teaching with each GST than the survey sample. Consistent with the survey sample, Elizabeth expressed strong confidence for teaching with the Google platforms (5.00 for Google Earth, compared to survey M = 4.20, SD = 0.87; 5.00 for Google Maps, compared to survey M = 4.31, SD = 0.79). Contrary to the survey sample, Elizabeth reported being confident for teaching with geographic information systems (4.00, compared to survey $M = 2.37$, $SD = 1.38$).

Table 6.9

Elizabeth's Reported Confidence for Teaching with Commonly-Used GST

GST	Score
Aerial photography	5.00
Google Earth	5.00
Google Maps	5.00
Geographic Information Systems	4.00
Global Positioning System	4.00
Satellite Imagery	5.00

School characteristics. Everton College is an independent school for students from Years 7-12. For the 2015 school year, student enrolments numbered 875, with indigenous students and students with a language background other than English accounting for 1% and 3% of the student population respectively (ACARA, 2016b).

Everton College's Index of Community Socio-Educational Advantage value is 1145 and is, therefore, above the national average of 1000 (ACARA, 2016b). The distribution of the school's students based on ICSEA is represented in Table 6.10.

Table 6.10

Distribution of Everton College Students Based on ICSEA

	Bottom quarter	**Middle quarters**		**Top quarter**
School Distribution	1%	10%	26%	63%
National Distribution	25%	25%	25%	25%

Source: ACARA, 2016b

National Assessment Program – Literacy and Numeracy (NAPLAN) results. NAPLAN results for students in Year 7 at Everton College reveal that students performed substantially above the national average for reading and above the national average for all other testing areas. In Year 9, students achieved results substantially above average in persuasive writing and above the national average in reading, spelling, grammar and punctuation and numeracy.

Teaching structure for geography. Teaching and learning at Everton College is centered on the International Baccalaureate (IB) framework, namely the Middle Years Program (MYP) for students from Years 7-9 and IB Diploma in Years 10 -12. Within the IBMYP, history and geography are taught together under the subject “Individuals and Societies.” In Years 11 and 12, students have a choice in pursuing geography within the IB Diploma framework or the South Australian Certificate of Education (SACE). Elizabeth states, “the majority of our students do SACE at our school.” The International Baccalaureate is strongly aligned with the *Australian Curriculum*. The IB’s focus on criterion-based assessment is the major point of departure from the *Australian Curriculum* at Everton College. For teaching geography content, Elizabeth states “I’m following directly the geography curriculum for ACARA and that would be the same for all our learning areas in the school.”

Technology access. Everton College has an active BYOD policy which has been in place for the past six years. As a result, all students from Years 7-12 are equipped with laptop computers in the classroom. Internet access at the school is robust and reliable: “Like all networks’, Elizabeth stated, “it has its days but the majority of the time it’s a pretty flawless system.” Elizabeth acknowledges that her school is well-provisioned for technology-enhanced learning and believes good access to technology supports her teaching: “it makes a huge different to teaching, to pedagogy, to how you go about doing things because you’ve got that reliability.”

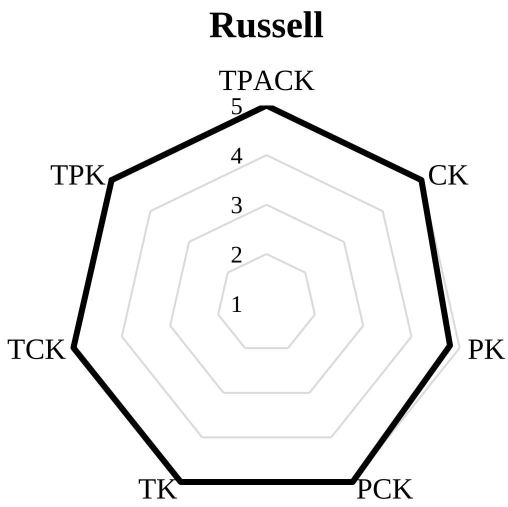
6.2.6 Russell

Russell has been teaching geography in schools for over twenty years with experience teaching students from Years 7-12 in independent schools in Victoria. At his school, Fairvale Grammar School, Russell has held responsibility for geography teaching in Years 7, 8 and 10 as well Years 11/12 VCE geography. Additionally, Russell has held the positions of Head of Geography and Head of Academic Computing at the school. Russell currently also holds a sessional position as a university lecturer in Humanities education at the local university.

Geography teaching experience and education background. Russell’s lengthy career in geography education is augmented by postgraduate level qualifications in geography and geography education. After completing a Bachelor of Education (Secondary) with focus areas in geography and history education, Russell has gone on to further study geo-informatics (the science of geospatial information) at the Masters level and he has completed a research Master of Arts in Geography Education at a European university.

Russell's education and experience in geography education has seen him take on an active role in his local professional geography teaching association and he has been a panel member for developing *AusVELS*, the Victorian expression of *Australian Curriculum: Geography*. As a champion for the inclusion of geospatial technologies within geography education, Russell has developed and facilitated a number of professional learning workshops supporting other teachers to implement GST in their teaching.

TPACK for teaching with GST. Russell's self-reported TPACK for teaching with geospatial technologies is reported in Figure 6.6.



CK	PK	PCK	TK	TCK	TPK	TPACK
5.00	4.80	5.00	5.00	5.00	5.00	5.00

Figure 6.6. Russell's self-reported TPACK.

Russell’s mean scores in each of the TPACK domains are higher than the means for the survey sample. Russell’s responses to the scale and single items with the *GST4GEOG* survey demonstrate that Russell feels highly knowledgeable about embedding geospatial technologies within his geography teaching.

Confidence for teaching with commonly-used GST. Russell’s responses to the Likert-scale items describing his confidence for teaching with commonly-used GST in geography education is reported in Table 6.11. Consistent with the survey, Russell reported high levels of confidence for teaching with the Google platforms, Google Earth (5.00) and Google Maps (5.00). Russell reported higher levels of confidence than the survey sample for teaching with aerial photography (5.00, compared to survey M = 3.98, SD = 1.07), satellite imagery (5.00, compared to survey M = 3.78, SD = 1.15) and GPS devices (5.00, compared to survey M = 3.29, SD = 1.28). While Russell also reported being less confident for teaching with geographic information systems (4.00), his response was nonetheless still higher than the sample mean (M = 2.37, SD = 1.38).

Table 6.11

Russell’s Reported Confidence for Teaching with Commonly-Used GST

GST	Score
Aerial photography	5.00
Google Earth	5.00
Google Maps	5.00
Geographic Information Systems	4.00
Global Positioning System	5.00
Satellite Imagery	5.00

School characteristics. Fairvale Grammar School enrols students from F-12. In 2015, enrolments numbered 1343 across the Junior (F-Year 6) and Senior (Year 7-12) school campuses. One-percent of students identified as being Aboriginal or Torres Strait Islander, while 6% of students possessed a language background other than English (ACARA, 2016b).

The school's Index of Community Social- Educational Advantage (ICSEA) value is 1135, above than the national average of 1000 (ACARA, 2016b). The distribution of the school's students based on ICSEA is presented in Table 6.12.

Table 6.12

Distribution of Fairvale Grammar School Students Based on ICSEA

	Bottom quarter	**Middle quarters**		**Top quarter**
School Distribution	3%	10%	29%	59%
National Distribution	25%	25%	25%	25%

Source: ACARA, 2016b

National Assessment Program – Literacy and Numeracy (NAPLAN) results. NAPLAN results for Fairvale Grammar School show that Year 7 students performed substantially above the national average in reading, above the national average in grammar and punctuation and numeracy and close to the national average in persuasive writing and spelling. Year 9 students performed substantially above the national average in reading, grammar and punctuation and numeracy and above the national average in persuasive writing and spelling.

Teaching structure for geography. The teaching structure for geography education at Fairvale Grammar School is different for each of the secondary school year groups. In Year 7, students study geography as a stand-alone discipline for 100 minutes over two classes per week over the entire school year. In Year 8, students study geography for three 50 minute periods per week for a semester. In Year 9, geography is taught as an interdisciplinary subject combining history and geography. The subject is theme-based rather than content-based, although Russell believes history education is the dominant lens through which students' learning takes place. Geography education, in its various incarnations, is compulsory for students from Years 7-9. In Year 10, geography is an elective which can be studied for 200 minutes per week over the course of the year. Victorian Certificate of Education (VCE) Year 11/12 geography is also a student elective which can be studied for 200 minutes per week in all school terms. Geography from Years 10-12, however, is only taught if deemed viable by the school's administrators. During years of low student enrolments into geography, the classes have not run.

Technology access. A technology provision policy is enacted at Fairvale Grammar School which sees all students and teachers equipped with laptop-tablet hybrid computers (Microsoft Surface computers). A recent change in the school's technology policy also allows students to use their personal mobile devices (e.g. smartphones, iPads) while at school, however students are still banned from using the devices in the classroom. A number of teachers, however, have begun experimenting with using student mobile devices for learning activities.

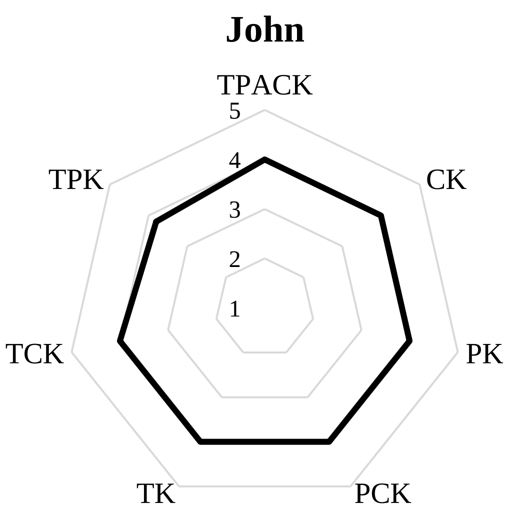
6.2.7 John

John presents a point of comparison to the classroom-based teachers featured in this research. John is the principal-educator at an environmental centre attached to a national park on Australia’s east coast. John does not have his ‘own class’ per se. Rather, teachers bring their students to John on fieldtrips to the national park and John facilitates students’ participation in fieldwork activities based on the natural and built environments of the local area. John’s participation in this research and his unique teaching context serves to further draw attention to the role of context in teachers’ development and enactment of TPACK for teaching with GST.

Geography teaching experience and education background. While John has been a teacher for 23 years, he began his career as a ranger with NSW National Parks. During his final year of university study for a Bachelor of Science with a major in applied physical geography, John began working as an Education Officer within the National Park Service. He worked on a program targeting school students which included using some GIS functions. These experiences encouraged John to pursue a career change to education. Following a one-year initial teacher education program, John taught science in secondary schools for ten years before becoming principal-educator at the environment centre.

Fifteen years ago, John was awarded a scholarship from the NSW Government to examine how national parks in the United States of America (USA) developed and facilitated learning programs for schools. While travelling in the USA, John attended the Esri Education User Conference in San Diego. Esri, as the largest commercial producer of GIS software, drew together geography professionals, government agencies, researchers and educators to discuss best-practice for using GIS in public and professional life. John's experiences at the Esri conference sparked his interest in using GIS for teaching in the secondary school and also made him aware of the significant barriers to GIS implementation in schools: "I came back from all that reaching the conclusions that the schools in the US were having the same problems that schools in Australia were having in implementing industry standard GIS." This realisation led John to pursue self-directed professional learning about how to implement Google Earth in the classroom. John has been using Google Earth with students since the mid-2000s.

TPACK for teaching with GST. John's self-reported TPACK for teaching with geospatial technologies is reported in Figure 6.7.



CK	PK	PCK	TK	TCK	TPK	TPACK
4.00	4.00	4.00	4.00	4.00	3.80	4.00

Figure 6.7. John's self-reported TPACK.

John reported slightly lower pedagogical knowledge than the sample mean (John's M = 4.00; sample M = 4.36, SD = 0.46), while his content knowledge (CK) scores were consistent with the sample mean. In the technology-related domains, John reported higher than average scores. This perhaps indicates that John feels most sure about his geography pedagogies when they are supported and enhanced by the technology.

Confidence for teaching with commonly-used GST. John's responses to the survey indicating his confidence for teaching with commonly-used geospatial technologies are reported in Table 6.13.

Table 6.13

John's Reported Confidence for Teaching with Commonly-Used GST

GST	**Score**
Aerial photography	4.00
Google Earth	5.00
Google Maps	4.00
Geographic Information Systems	2.00
Global Positioning System	5.00
Satellite Imagery	4.00

John expressed a high degree of confidence for teaching with most of the commonly used GST in geographical education. In particular, John reported being very confident in teaching with Google Earth (5.00) and GPS (5.00). Consistent with the survey sample, however, John reported being less knowledgeable about teaching geography with geographic information systems (2.00) which perhaps echoes his belief that Google Earth is more useful than GIS as a tool for teaching geography.

Centre characteristics. As John's environmental education centre does not have a regular student cohort, it is not possible to collect evidence of the schools' socio-educational standing or student NAPLAN results. However, the aims, activities and staffing structure at the centre are still important contextual considerations that shape John's development and enactment of TPACK for teaching with geospatial technologies.

Aims of the environmental centre. The NSW Department of Education operates 27 environmental education centres (and two zoo education centres) across the state. The purpose of the centres is to support students in their learning of environmental education and sustainability through the provision of targeted education programs that draw on the distinct features of the local environment of each centre. The broad focus on environmental education and sustainability means that the centres are frequented by schools for both science and geography education programs. Qualified teachers in each centre are responsible for designing and facilitating education programs relevant to each centre's geographical location. At John's centre, education programs for Years 7-12 focus on exploring sustainable ways of managing the physical and built environments at the national park.

Activities at the environmental centre. John's environmental education centre began operation in 1976. Primarily, the purpose of the centre was to support fieldwork for science and geography within the secondary school and to facilitate more general "nature studies" with primary schools. The mandate of the centre has changed over time, however, and the centre now offers programs in a range of learning areas, including environment education, outdoor education and student wellbeing programs. In addition to traditional fieldwork activities (such as taking photographs, doing field sketches, visual assessments of human impact etc), the centre also provides for overnight camps and resilience building activities for F-12 students. The changing focus of the environment education centre represents a shift away from pure fieldwork to a more holistic approach to the education of the student as a whole.

Staffing structure. John is the principal-educator at the environmental education centre. As principal-educator, John is leader of the centre and sole full-time teaching employee. John is responsible for the design and delivery of education programs in addition to leading a number of casual staff – teachers and administrative staff – who also facilitate and support the promotion and delivery of programs. The staffing structure at the environment centre offers John significant scope to experiment with his teaching practice. John is able to design, trial and test geospatial technology applications with a wide range of students. As a result, John believes that he has a strong grasp of the types of geospatial technologies that can be used for various geography tasks. This sense of freedom to experiment is enjoyable for John and has been a key motivator for him in retaining his position as principal-educator for the last 13 years: "it's a great place to work because you've sort of got your own school, but there's other people's students who come to me and I just have a lot of fun, basically!"

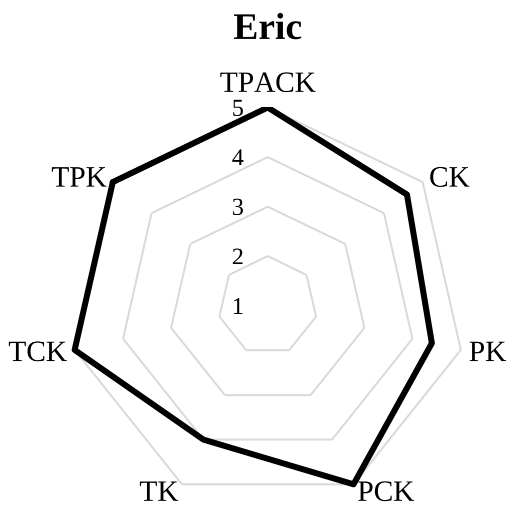
Technology access. John has a number of GPS devices available to him which he uses for a range of geo-caching/orienteering style activities within the centre's education programs. Additionally, John makes use of the technology supplied by the schools who visit the centre. These schools are largely drawn from the NSW Government school catchment area located near the national park. The Digital Education Revolution (DER), a national funding initiative of the Australian Government, provided for a significant influx of funding to schools (some $2.1 billion across Australia) to support digital infrastructure in schools. In NSW, the rollout of the DER funding included the provision of netbook computers to students in Year 9. John has capitalised on the availability of the netbook computers by designing a variety of learning opportunities for using the computers both to support the education programs offered at the centre and for post-visit follow up activities in schools. While the availability of the netbooks has offered greater opportunity to undertake learning with geospatial technologies, the small size of the netbook screens has caused John some challenges regarding the presentation and use of programs such as Google Earth on these devices.

6.2.8 Eric

Eric has been a teacher of geography for 29 years and has taught students from Years 7-12 in government and independent schools in New South Wales. At Holly Road School, Eric is the Head of Geography, responsible for coordinating the provision of geography subjects at the school, collating and reporting student achievement, and encouraging teachers at the school to pursue professional learning opportunities in geography.

Geography teaching experience and education background. Eric holds Bachelor level qualifications in geography and teaching. A trained English and geography teacher, Eric initially worked within the NSW Government school system before moving into the independent school system after 14 years of public service. Eric has now taught geography at Holly Road School for 15 years, during which time he pursued further tertiary qualifications, including a Masters degree focused on the role of computers in education. Eric's breadth of experience in geography teaching and knowledge of the pedagogical application of computers for teaching has provided him with the skills and desire to conduct his own professional learning events for other NSW teachers about the use of technology in geography teaching.

TPACK for teaching with GST. Eric's self-reported TPACK for teaching geography with geospatial technologies is represented in Figure 6.8.



CK	PK	PCK	TK	TCK	TPK	TPACK
4.60	4.40	5.00	4.00	5.00	5.00	5.00

Figure 6.8. Eric's self-reported TPACK.

Eric reported being highly knowledgeable in each of the TPACK domains. While Eric reported being the least knowledgeable in the technology knowledge domain, his self-reported TK was still higher than the survey sample mean (Eric's $M = 4.00$; sample $M = 3.52$, $SD = 0.83$).

Confidence for teaching with commonly-used GST. Eric's responses to the Likert-scale items describing his confidence for teaching with commonly-used GST for geography education is reported in Table 6.14. Consistent with the survey, Eric reported high levels of confidence for teaching with the Google platforms, Google Earth (5.00) and Google Maps (5.00). Eric reported higher levels of confidence than the survey sample for teaching with aerial photography (5.00, compared to sample $M = 3.98$, $SD = 1.07$), satellite imagery (5.00, compared to sample $M = 3.78$, SD = *1.15*) and GPS devices (5.00, compared to sample $M = 3.29$, $SD = 1.28$). While Eric also reported being less confident in teaching with geographic information systems (4.00), his response was nonetheless still higher than the sample mean ($M = 2.37$, $SD = 1.38$).

Table 6.14

Eric's Reported Confidence for Teaching with Commonly-Used GST

GST	**Score**
Aerial photography	5.00
Google Earth	5.00
Google Maps	5.00
Geographic Information Systems	4.00
Global Positioning System	5.00
Satellite Imagery	5.00

School characteristics. In 2015, Holly Road's enrolments numbered 2005 across the junior (F-Year 6) and senior school (Years 7-12). Less than 1% of the school's students identified as being of Aboriginal or Torres Strait Islander descent, while 16% of the school's students possessed a language background other than English (ACAR, 2016b).

The school's ICSEA value is 1193, above the national average of 1000 (ACARA, 2016b). The distribution of the school's students based on ICSEA is presented in Table 6.15.

Table 6.15

Distribution of Holly Road School Students Based on ICSEA

	Bottom quarter	**Middle quarters**		**Top quarter**
School Distribution	0%	2%	14%	83%
National Distribution	25%	25%	25%	25%

Source: ACARA, 2016b

National Assessment Program – Literacy and Numeracy (NAPLAN) results. NAPLAN results for Holly Road School students in Year 7 and Year 9 indicate that the students performed substantially above the national average in all testing areas.

Teaching structure for geography. The teaching structure for geography education at Holly Road School differs for each schooling year. In Years 7-10, the school is guided by NSW curriculum documentation for geography which mandates 100 hours for Stage 4 (Years 7 and 8) and Stage 5 (Years 9 and 10). In Year 7, students solely study history, while geography is taught exclusively in Year 8. In Year 9, students can choose to participate in an elective geography subject. In Year 10, history and geography are taught simultaneously. In Years 11 and 12, preparation and completion of NSW HSC geography is the key aim with students studying seven lessons of geography over a two-week timetable. The school currently operates four classes in Year 11 and three classes in Year 12.

Technology access. Eric did not perceive any barriers to accessing technology for geography teaching and learning at Holly Road School. Wi-Fi access is readily available and poses few reliability problems. In each geography classroom, there are a minimum of 13 computers for students to use exclusively for geography education. A BYOD policy will be enacted within the next two years and students' use of their own devices will be a mandatory requirement across the school.

6.2.9 Summary of Early Adopters' Professional Contexts

Rich qualitative descriptions of the early adopters' professional contexts have been provided here as both previous research and the findings from the *GST4GEOG* survey confirm that context influences teachers' decisions to adopt geospatial technologies in geography teaching and their TPACK (Baker, Palmer & Kerski, 2009; Battersby, Golledge & Marsh, 2006). These descriptions highlight both differences and similarities in early adopters' contexts.

In all but one case (Sarah), the early adopters who participated in this research work in school contexts that have higher than average ICSEA values. All but Sarah also work in non-government school contexts (that is, the Catholic or independent school sectors). Sarah, on the other hand, works in a government school which has an ICSEA value of 971. This is 29 points below the national average. While nearly all of the early adopters who participated in the qualitative research phase of this study work in non-government school contexts, this was not found to be consistent with the overall sample from the survey: 58% of these early adopters reported working in government school contexts. This suggests that, although concerted efforts were made to recruit participants from a range of teaching backgrounds in the qualitative research phase, the number of interviewed early adopters who work in government schools (*n* = 1) is not representative of the population of early adopters of GST in geography teaching. This is a limitation of this study that could be a focus for future research efforts.

The key findings from this chapter are:

- Early adopters hold a diverse range of educational experiences/qualifications – some early adopters have past educational experiences with geography and geospatial technology, while other early adopters do not have specialised backgrounds. This finding suggests that a geography/GST background is not critical for GST adoption in secondary geography teaching.
- All but one teacher worked in a school where students achieved higher than average scores on NAPLAN tests. While NAPLAN results have been highly scrutinised (Johnston, 2017), the findings do provide some evidence of higher academic achievement of the schools' students. Teaching higher performing students may make teachers more comfortable in using sometimes complex GST applications in the classroom.
- All but one teacher reported high levels of technology access. Teachers may find it more achievable to adopt GST if they are confident in their on-going access to technology for teaching.

While these rich descriptions provide some insight into the context conditions that could influence how early adopters use geospatial technologies in geography teaching, further analysis of teachers' contexts is necessary to adequately address

RQ2. How do context barriers and enablers influence early adopters' use of geospatial technologies in their geography teaching? This analysis is presented in Chapter Seven.

6.3 Chapter Conclusion

The context and micro-politics of schools make a big difference to the capacity of teachers to innovate in general (Ball, 1987; Buchanan, 2016) and employ GST in geography education in particular (Baker, Palmer and Kerski, 2009). Clarke (2003, p.100) noted that "in order to develop a holistic understanding of the effect of change in schools a perspective is required that considers the socio-political and cultural context of an organisation." This chapter has shared the raw material of the contexts in which participant early adopters were working.

The purpose of this chapter was two-fold. First, the early adopters who participated in the qualitative phase of this research were introduced, drawing attention to their self-reported TPACK and confidence for teaching with commonly used geospatial technologies. Second, the early adopters' professional contexts were described in response to survey findings which confirmed that context influences teachers' adoption decisions.

Chapter Seven is concerned with identifying the influence of context on the early adopters' use of geospatial technologies in their geography teaching. Thematic analysis of the teachers' interview responses identifies context conditions that both enable and constrain their capacity to act on their technological, pedagogical and content knowledge in their given professional contexts.

Chapter 7

The Influence of Context on Early Adopters' GST Use

7.1 Introduction

Previous TPACK-related research has argued that the place of context within the framework has been consistently ignored or downplayed (Angeli & Valanides, 2009; Rosenberg & Koehler, 2015; Swallow & Olofson, 2017). Critiques supporting this contention argue that political, economic, social and cultural context conditions influence the practice of teaching with technology (Brantley-Dias & Ertmer, 2013; Porras-Hernández and Salinas-Amescua, 2013). These context conditions influence how teachers use technology in the classroom and their expression of TPACK within their teaching. In investigating the contexts of early adopters of GST, this chapter presents some findings that address RQ2. How do context barriers and enablers influence early adopters' use of geospatial technologies in their geography teaching?

Although there have been a variety of studies identifying barriers to teachers' use of geospatial technologies in teaching (Baker, 2005; Dascombe, 2006; McClurg & Buss, 2007), few studies have yet to examine the context conditions which support teachers in their expression of their TPACK. To identify these enablers, to examine enduring or emergent barriers and to situate these context conditions within the ‘levels’ proposed by Porras-Hernández and Salinas-Amescua (2013), results from the *GST4GEOG* survey and interviews with the early adopters are explained and discussed in this chapter.

7.2 Macro, Meso and Micro Context Conditions

As discussed in Chapter Three, the adapted TPACK framework offered by Porras-Hernández and Salinas-Amescua (2013) is used in this study to guide discussion of the context conditions that influence early adopters’ use of geospatial technologies in geography teaching. As this chapter extensively utilises this framework to inform the analysis of these context conditions, it is timely to repeat the definitions of macro, meso and micro context conditions offered by Porras-Hernández and Salinas-Amescua (2013) and outlined in Chapter Three:

Macro context conditions are “social, political, technological, and economic conditions. These include the rapid technological developments worldwide, which require constant learning, as well as national and global policies that, in the case of teacher technology integration, become especially relevant” (p. 228).

Meso context conditions are “social, cultural, political, organizational, and economic conditions established in the local community and the educational institution” (p. 288) and include the attitudes held and decisions made by school administrators, parents and the community about the implementation of technology in teaching.

Micro context conditions reflect the “in-class conditions for learning. These conditions may include available resources for learning activities, norms, and policies, as well as the expectations, beliefs, preferences, and goals of teachers and students as they interact" (p. 230).

A visual representation of Porras-Hernández and Salinas-Amescua's (2013) TPACK context framework is presented in Figure 7.1.

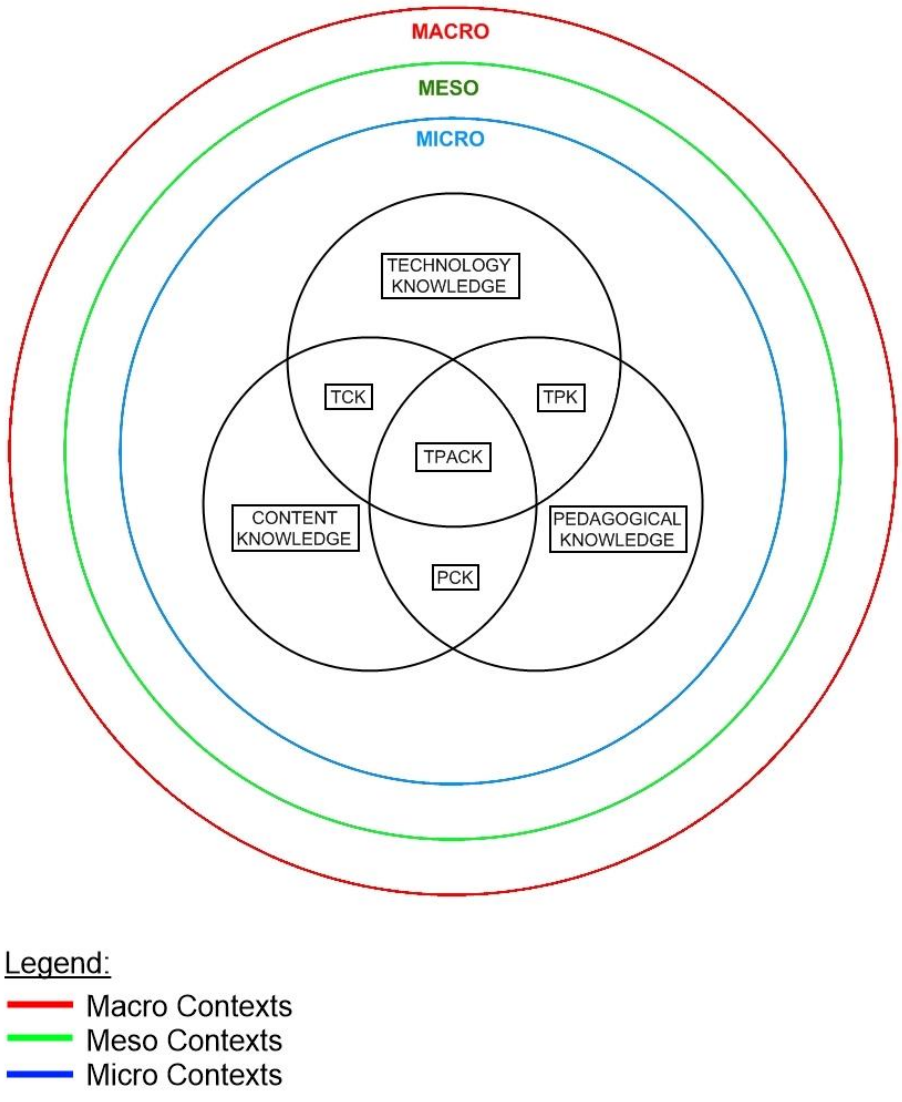


Figure 7.1. Levels of TPACK context (adapted from Porras-Hernández and Salinas-Amescua's (2013))

7.3 Known Barriers and Enablers of GST in Geography Teaching

Studies, particularly those published prior to 2010, have examined barriers to the implementation of geospatial technologies in classrooms. As outlined in Chapter Two, common barriers to GST implementation include limited instructional time for teaching with GST, limited teacher knowledge about GST, and limited access to computers in schools (Baker, 2005; Kulo & Bodzin, 2011; Wheeler et al., 2010). Given the time that has elapsed between these earlier studies, the proliferation of geospatial technologies commercially since that time, and the inclusion of GST within *Australian Curriculum: Geography,* it is necessary to re-assess the validity of these barriers for contemporary geography teaching and also to bring to light enablers of GST teaching practice.

7.3.1 Survey Results

Data were collected from the *GST4GEOG* survey about the factors that influence early adopters' decisions to use geospatial technologies for teaching secondary geography. Specifically, early adopters were asked to provide a written response to the following questions: What factors influence your decisions about using geospatial technologies in the classroom? What would help or encourage you to use geospatial technologies in your teaching? The analysis of this quantitative data is presented in Chapter Five, however, it is useful to reiterate these results here for the purposes of comparing them to those findings derived from the interviews (Table 7.1).

Table 7.1

Factors that Influence Teachers' Use of Geospatial Technologies in Teaching

Factor	Frequency	Percent (%)
Cost as barrier	17	33.3
Technology access as barrier	11	21.6
Limited teacher knowledge as barrier	11	21.6
Teaching and planning time as barrier	8	15.7
Network/Internet speed as barrier	6	11.8
Curriculum/Task relevance	6	9.8
Student engagement	5	9.8
Technology compatibility as barrier	4	7.8
Ease of use as enabler	4	7.8
Difficulty of use as barrier	3	5.9
Web-based GST as enabler	3	5.9
[Lack of] school support as barrier	2	3.9

N = 51

The survey results indicate that, consistent with previous studies, early adopters perceive the cost of geospatial technologies, limitations on technology access in the classroom and limited teacher knowledge for teaching with GST as enduring barriers to their GST implementation in geography teaching (Kinniburgh, 2008; Rød, Larsen & Nilsen, 2010; Wheeler et al., 2010). Fewer early adopters perceived enablers of practice, although ease of use (n = 4) and the availability of web-based GST (n = 3) were acknowledged by some of the teachers.

7.4 Interview Results

Analysis of teacher interviews revealed that *macro*, *meso* and *micro* level conditions influence early adopters' use of geospatial technologies in their geography classroom. These early adopters, introduced in Chapter 6, are given pseudonyms in this study: Sarah, Liam, Georgia, Melissa, Elizabeth, Russell, John and Eric. Given early adopters' predispositions to trial the implementation of an innovation before their later adopting peers (Rogers, 2003), the barriers (and enablers) of their practice are a strong indicator of policy, curriculum, teacher training and school resourcing issues that must be addressed if GST is to continue to diffuse in Australian geography classrooms.

In keeping with Porras-Hernández and Salinas-Amescua's (2013) framework, this chapter presents the research findings from a policy-to-practice perspective; first macro context conditions are presented, followed by meso context conditions and then micro context conditions.

7.5 Macro Context Conditions

Thematic analysis of interview data using Braun and Clarke's (2006) thematic analysis guidelines, discussed in depth in Chapter Four, was conducted to reveal themes and patterns within and across the early adopters' interviews. Following Braun and Clarke's six-step procedure, initial codes were generated from an extensive and rigorous review of the interview transcripts and were then collated into themes. These themes were then 'mapped' to identify the "relationship between the codes, between themes, and between different levels of themes (e.g. main overarching themes and sub-themes within them)" (Braun & Clarke, 2006, p. 89-90). This thematic mapping is represented in Figure 7.2. Ten initial codes were generated and analysis of the relationship between the codes resulted in the identification of three overarching themes. These themes were '*curriculum design and implementation'*, '*technology provision and data access policy*' and '*geospatial technology capabilities and commercialisation.*'

7.5.1 Technology Provision and Data Access Policies

Three of the early adopters referred to context conditions relating to the provision of technology in schools and policies supporting the pubic dissemination of geospatial data as enablers of geospatial technologies in geography education. John spoke about the New South Wales Government's provision of laptops to schools as part of the Digital Education Revolution (DER) policy and how this was instrumental in pushing him to design learning tasks using geospatial technologies:

> John (p. 12, 280-288): You're constantly thinking, what can I get students to do with this knowledge? Google Earth is pretty easy to use. That was about the time that the Digital Education Revolution funding was coming out in schools so students had these laptops and so we developed some student tasks which were focused on using the laptops in the classroom.

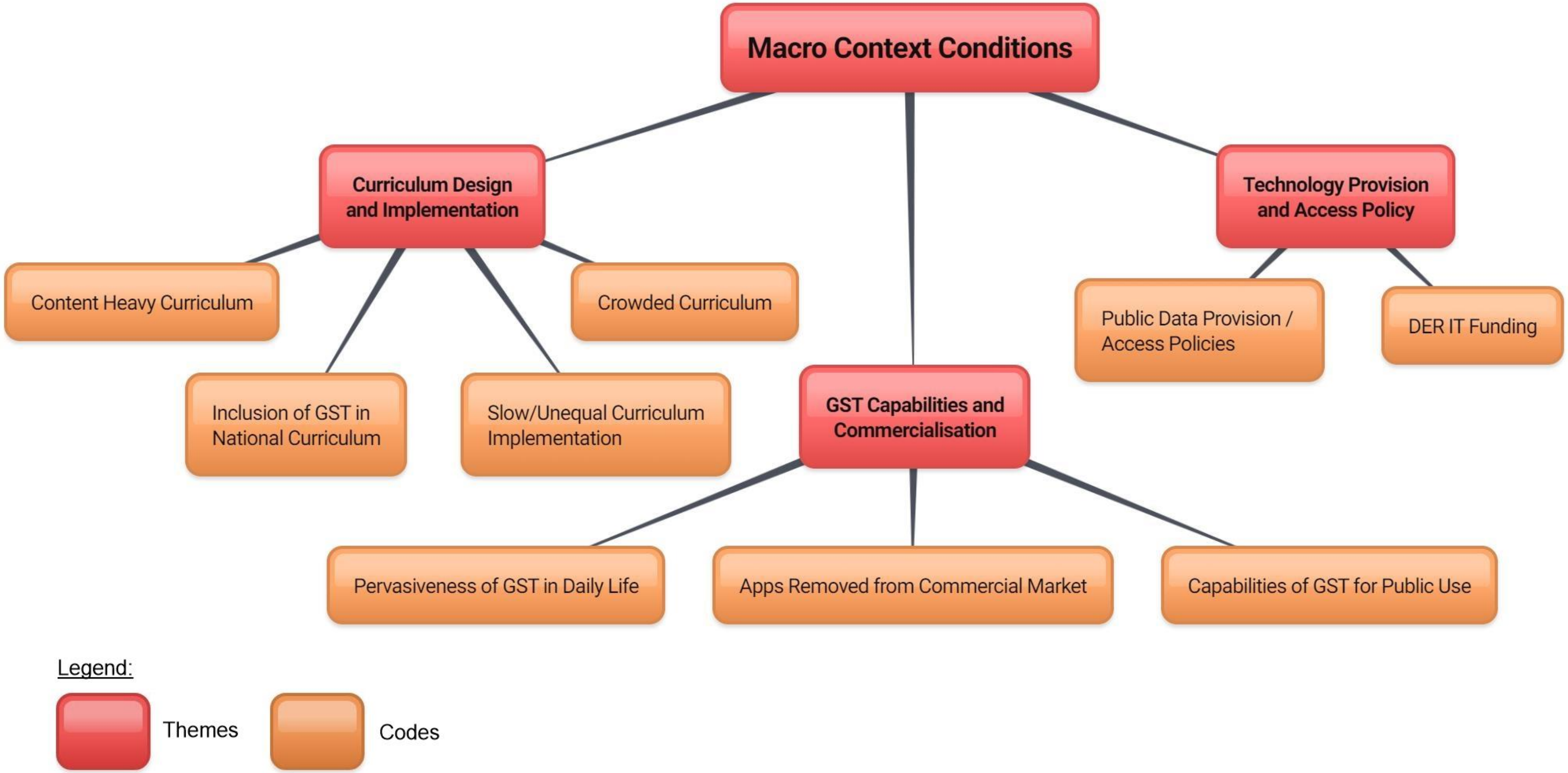


Figure 7.2. Mind-map: Macro context conditions.

John’s time in the United States of America learning about how geospatial technologies were being adopted in American schools instilled in him the desire to bring geospatial technologies into his teaching in Australia. The experience of American teachers in adopting GST demonstrated to John that many of the barriers to using the technology were universal:

> John: At that point, I came back from all that reaching the conclusions that the schools in the US were having the same problems that schools in Australia were having implementing industry standard GIS in terms of not having the people who are trained in it, insufficient time in the teaching cycle to really get the time to teach kids the skills.

Despite his knowledge of the many barriers to GST teaching, John nonetheless saw an opportunity to capitalise on the DER policy. The NSW DER laptop scheme provided the conditions for John put into practice his ideas for embedding GST into this teaching.

Both Eric and Russell commented on how policies which allow geospatial data to be freely accessible to the public allowed them to use that data for teaching and learning in geography. Eric, despite teaching in school where professional-grade GIS software and datasets are available to support geography teaching and learning, still believes that free, publicly available geospatial data offers significant opportunities for teaching:

> Eric (p. 5, 101-104): I do a fair bit of stuff now with Google Earth and the NSW Government has just released a whole lot of data through a thing called NSW Globe 6.

Russell explained how public access to geospatial data has enabled him to collect resources he requires for teaching geography:

Russell (p. 26-27, 645-648): No, there's heaps of resources. I haven't gone out of my way to find any of this. Data.gov.au, you can download KML and SHP files and all sorts of stuff. It's not necessarily extensive but it's there.

Russell's statement that "I haven't gone out of my way to find any of this stuff" speaks to his personal interest in collecting websites and resources which incorporate geospatial data in some form. Russell's strong PCK allows him to translate this spatial data into a resource suitable for teaching. Russell's interest and knowledge about where to source geography education resources that incorporate geospatial technologies (TCK) is enabled by the contextual conditions that allow the provision of publicly available geospatial data.

7.5.2 Curriculum Design and Implementation

Three of the early adopters identified curriculum design and implementation conditions which constrained their ability to use geospatial technologies in their geography teaching. Both Sarah and Eric described feelings of pressure to respond to a content-heavy curriculum which they perceived allowed for little extra time to experiment with geospatial technologies.

Sarah (p. 4, 169-174): As of 2017, the Department [of Education] and obviously through the *Australian Curriculum*, we need to be able to fit in not only our history curriculum, our geography curriculum, but also our civics and citizenship curriculum and business studies.

Sarah's comment speaks to concerns about the 'overcrowding' of the Humanities and Social Sciences (HASS) curriculum, a critique which was also levelled in the Australian Government's own recent review of the *Australian Curriculum* (ACARA, 2015). Although yet to implement the *Australian Curriculum* in geography at the time of the research, Eric, in his school in NSW, also expressed concerns about unrealistic demands on teaching brought about by curriculum overcrowding:

> Eric, (p. 16, 393-396): We're pretty content heavy. We're too content heavy in NSW and that drives the beast a fair bit so you just hope the kids understand things as they go through.

For Eric, context conditions in NSW relating to curriculum design and implementation work to constrain his capacity to provide for deep learning of geography. The need to work through a large amount of content gave Eric little time to confirm students' understanding of the geography content and skills he was teaching.

Liam also identified curriculum design and implementation conditions that limited his opportunities to use geospatial technologies with senior secondary school students. Liam particularly noted a lack of curriculum continuity from the Years 7-10 *Australian Curriculum* and the NSW Higher School Certificate (HSC) syllabus (Years 11 and 12). While the *Australian Curriculum* emphasises the use of geospatial technologies in geography teaching from Years 7-10, the HSC syllabus includes no such provisions:

> Liam (p. 3-4, 62-77): Kids are still more used to using paper maps, particularly when they get to the HSC level, because the test is on a broadsheet topographic map and that sort of thing… There's no relevance after Year 11 in HSC geography in NSW to go with GIS. So it doesn't become a thing where I actually need them to use it in this context. The *Australian Curriculum* for geography in NSW doesn't kick in until 2017 and that only goes up to Year 10. So Year 11 and 12 is no change and that's one of the issues I'm seeing in the continuity [of the curriculum]. They're trying to embed GIS

into the *Australian Curriculum* but it doesn't really translate into senior study.

The need to prepare students for the HSC Geography test in which there are no references to geospatial technologies discouraged Liam from using the technologies with his senior classes. Liam was constrained in his ability to enact his TPACK for teaching geography with GST by the HSC Geography curriculum requirements.

Eric indicated that a lack of clarity around the *Australian Curriculum* implementation timeline in his state was a key challenge for the school's planning and preparation for geography teaching.

> Eric (p. 23-24, 563-57): It's a little unclear for us because it's [the *Australian Curriculum*] is meant to come in for Years 7 and 9 in 2017 in NSW but we don't teach Year 7 and 9s the [previously compulsory] geography elective so we're wondering if that means 2018 for us. I'm seeking clarification on that. Typical NSW!

Given that the impetus for teachers to adopt geospatial technologies is clearly defined in the *Australian Curriculum*, unclear messages about curriculum implementation has the potential to cause confusion about the obligations on teachers to use GST. Such confusion could constrain teachers' enactment of their TPACK and the extent to which GST is implemented in the classroom.

Russell, on the other hand, was positive about the *Australian Curriculum*: "I think a huge step was to get [geospatial technologies] written in to the curriculum" (p. 27, 666-667). For Russell, the inclusion of geospatial technologies within the *Australian Curriculum* is an enabler of his GST practice. The *Australian Curriculum* lends legitimacy to GST use in the classroom by highlighting the relevancy of the technology to geography content and pedagogy.

Although teaching in a Year 12 context, Melissa also spoke to GST inclusion in the curriculum (in her case, the Victorian Certificate of Education) as an enabler of future practice:

> Melissa (p. 20, 482-490): [The VCE] is really quite specific and [geospatial technologies] were sort of vaguely in the study design before, [that is] in the previous study design, but weren't really being emphasised… For me, [the inclusion and emphasis of GST in the most recent design of VCE Geography] really emphasises the need to try and introduce as many different ways of assessing or addressing spatial technologies prior to Year 12 so it's not something new at that stage.

Melissa's comments also illustrate that she sees value in embedding geospatial technologies in the curriculum prior to senior secondary study, if only to improve students' likelihood of success in Year 12. The inclusion of geospatial technologies in the VCE geography exam similarly informs Melissa's rationale for using GST with her students:

> Melissa (p. 19, 457-462): In the sample exam, they put out … there's even been quite specific questions that might identify a list of types of spatial technologies and the students have to recognise which one would be most suitable to use in the example of fieldwork.

From her comments, it is clear that Melissa draws strongly on her knowledge of the curriculum content (CK), geography pedagogy (PCK) and knowledge of the student learning (PK) when designing and planning learning activities in her classroom.

7.5.3 Geospatial Technology Capabilities and Commercialisation

Three early adopters also identified how the commercialisation of geospatial technology applications, the increased capabilities of these applications and the pervasiveness of commercialised geospatial technologies in the 21st century have impacted on how and why they teach geography with GST. John and Elizabeth both commented on how the inclusion of geospatial technology applications on mobile devices has provided the impetus for them to move forward with their GST teaching agenda:

> Elizabeth (p. 3, 3-69): There's an evolution in the types of spatial technologies that we use in schools. You know, we've got things now that are so much more readily available, whether it be Google Earth suites down to the GPS on your phones, it's completely changed therefore how you go about these things [teaching with GST] is able to change as well.

The development of geospatial technologies in mobile phones enables Elizabeth to enact a different pedagogy (PK/TPK) that takes advantage of the increased capabilities of geospatial technology applications. Elizabeth's comments point to her understanding of how the inclusion of technology changes how teaching occurs (TPK).

John concluded that in today's society there is an expectation that spatial data is used to communicate information to the public:

> John (p. 5-16, 356-372): There's just more embedded spatial material in the resources that [teachers] use today. Ten years ago, you went to a webpage and there wasn't an embedded Google Earth map. There wasn't a prepared map that you click on and it would pop up with little pop-up windows. I think there's a much richer set of resources that people are finding natural in

the media. When there's an earthquake in Nepal, for example, there will be an interactive map on the ABC website talking about the story and you can click on things. That seems to be something that people expect now even though they haven't gone looking for it. It's just been created more for them.

John's comments illustrate how geospatial technologies have become a part of the lived experienced of 21st century consumers. Society's interest in geospatial information informs John's understanding of why teachers should use geospatial technologies in their teaching; that is, he appreciates that students need to learn about geospatial technology to equip them with the skills and knowledge that they need in order to be active and informed citizens.

John also has an awareness of the capabilities of commercial GST applications and how those capabilities can be utilised in the classroom (TPK):

John (p. 17, 400-405): There's a whole range of tools available to people and I think people increasingly use things like Strava for their running, jogging, and you can give the kids those things to use and it can do certain mapping tasks.

Likewise, Russell also demonstrates his TPK through in his assessment of the value of commercial geospatial technology applications (such as Google's mapping program, Google Earth) for opening up opportunities for geography teaching and learning:

Russell (p. 24, 579-583): Google Earth actually combines all three major categories of spatial technologies in one area. Satellite images, a layered map-base and the ability to use data collected from GNSS [global navigation satellite system/GPS] in the field. That's all three major areas as far as I'm concerned in one place.

The capabilities of Google Earth allow Russell to meet his objective of incorporating all three components of GST into his teaching. Russell's understanding of the capabilities of Google Earth for geography teaching and learning is an expression of his TPACK.

Reflecting on the professional learning resources he has created for other teachers, Russell also identified a potentially significant barrier to GST implementation: that is, the removal of geospatial technology applications from the market:

> Russell (p. 29): I was rather limited in the ability [to create tutorials for teachers] because there were so many applications, free apps that you could use. I couldn't put tutorials on there for all of them and teach everybody to use every app. Indeed, one app disappeared through the course of the writing. It became unavailable. It was taken off the iStore. This is a potential problem, that apps come and go. They'll certainly change.

Russell's comments highlight an important consideration for teachers' professional learning about geospatial technologies. Teachers may be more familiar or have more experience implementing particular GST applications in their classroom. The removal or adaption of these applications, therefore, may have implications for their on-going knowledge, confidence and interest in implementing GST in their teaching. The knowledge that teachers derive from professional learning experiences using particular GST applications may become obsolete if those apps are removed from the market.

7.5.4 Summary of Macro Context Conditions

From the early adopters' statements, it is clear that macro context conditions do influence teachers' expressions of their technological, pedagogical and content knowledge (TPACK) and constrain and enable their GST teaching (Figure 7.3). In particular, the early adopters described both barriers and enablers related to national/state curriculum design and implementation, public technology and data access policies, and geospatial technology capabilities and the commercialisation of those technologies. These barriers are largely consistent with those described by Trautmann and MaKinster (2010) who found that national course/curriculum requirements hindered geospatial technology implementation for two of their three case study teachers.

While clear barriers continue to exist at the macro level, the early adopters in this study also identified macro context conditions that enable their GST teaching practices. The early adopters considered open-access to GIS datasets from national and/or state online repositories to be a valuable way of accessing geospatial technology resources to use in class. Additionally, the increased availability of geospatial technologies for public use (such as web-based GIS and GST applications) were also considered enablers of early adopters' practice. These enablers do offer hope for increased GST diffusion amongst Australian geography teachers.

The macro context barriers are challenging realities for teachers, however. As decisions relating to national curriculum design and implementation are outside of the purview of individual classroom teachers, curriculum inconsistencies, overcrowding, and ambiguity are significant issues that may block further diffusion of GST in geography classrooms and the use of technology in education more generally (Jones & de Vries, 2009). Challenges stemming from macro context conditions, therefore, need to be addressed at the level of national and/or state policy, requiring concerted efforts from policy-makers to address these consistently reported barriers.

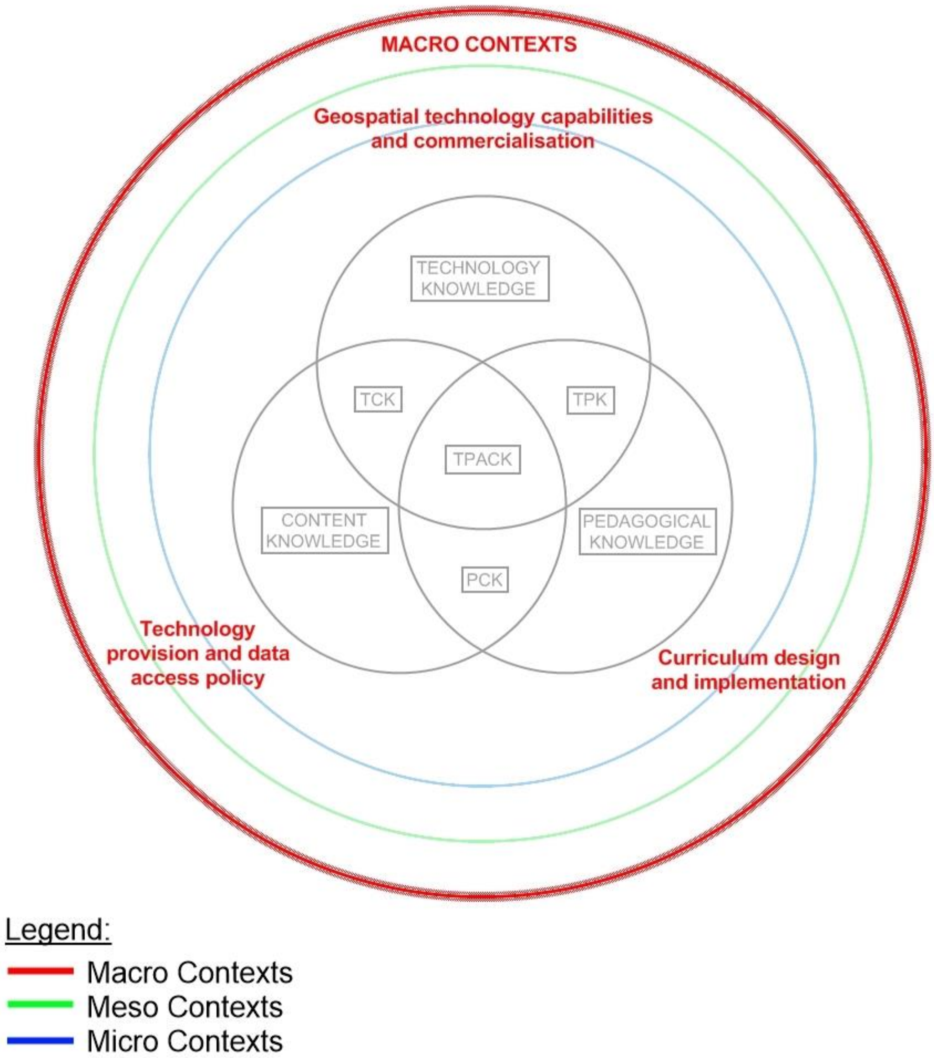


Figure 7.3. Influencing macro context conditions

7.6 Meso Context Conditions

The same thematic analysis procedure (Braun & Clarke, 2006) was applied to the analysis of interview data related to meso context conditions. This analysis revealed 16 meso context conditions influencing early adopters' use of GST in geography teaching. These themes were '*professional collaboration and networking* *opportunities*, '*challenges to technology implementation in schools', 'teacher education'* and '*whole school geography education challenges.'* The relationships between codes and themes are represented in Figure 7.4.

7.6.1 Professional Collaboration and Networking Opportunities

Four early adopters commented on six context conditions related to professional collaboration and networking opportunities that enable their enactment of TPACK and use of GST in geography education. These early adopters perceived opportunities to share resources, to engage in cross-disciplinary collaborative planning with other teachers, and to draw on the expertise of their professional contacts, as enablers of their GST practice. Melissa commented on the value of working collaboratively with other teachers teaching VCE Geography in other schools:

> Melissa (p. 19-20, 472-480): I'm going to do a case study on China with desertification this week with my girls and, fortunately, I'm part of a [VCE teaching] network so someone has already accessed stuff and they're looking at how remote sensing has been used to assess whether or not management strategies by the Chinese Government have actually impacted on the land.

For Melissa, the teaching network provides the context conditions that enable her to draw on the knowledge of teachers in other schools to support her own GST teaching in her geography classroom. By drawing on the collective knowledge of teachers in the network, Melissa is able to find resources and teaching ideas that support the integration of GST into geography content and pedagogy (TPACK). Melissa's use of these shared materials reflects her understanding of what makes an effective learning task using GST for learning geography; that is, she selects those learning tasks designed by other teachers which she believes appropriately combines geography content, pedagogy and technology. As these teaching materials are endorsed by members of her professional network, Melissa can have a good level of trust in the provenance of the resources.

Eric also underscored the value of working collaboratively with others in the pursuit of GST teaching. Eric's school funds the provision of professional grade GIS for use in the school's geography classrooms. Eric's interest and involvement in TeachMeet events and his drive to seek out new resources for his classroom has led to him developing a working relationship with a skilled GIS professional outside of the school. Eric talked about how he leverages this relationship to build GIS databases that are relevant to the geographical region in which the school is located:

> Eric (p. 3, 58-61): We still do ArcMap stuff and every time the new census data becomes available, I link up with a guy down in Crow's Nest and we put together a new [GIS] package. We're fortunate that we're pretty well resourced and the [fact that] census data keeps it updated is fantastic.

By leveraging his professional contact and by utilising publicly available geospatial data (see macro contexts), Eric is able to design teaching resources that link together geographical content (geospatial information) and technology (GIS). The census GIS databases are therefore an expression of Eric's TPACK; that is, his knowledge about the combination of geography content (CK) and technology (TK) and appropriate pedagogy (PK).

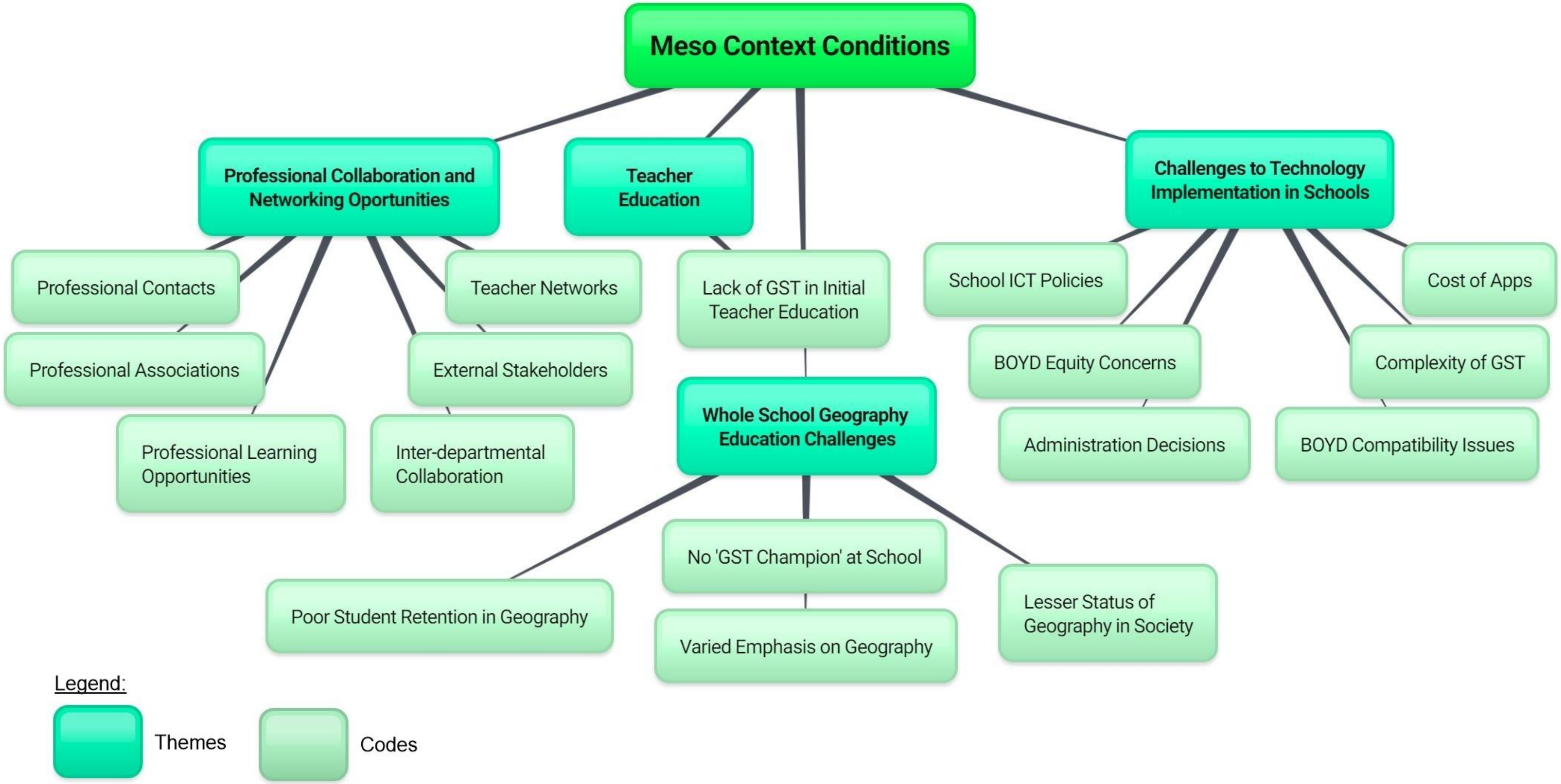


Figure 7.4. Mind-map: Meso context conditions.

John, in his role at an environmental education centre, perceives himself and his duties at the centre to be an enabler of other teachers' use of GST in the classroom. John provides pre-visit and post-visit support to teachers, visiting schools to discuss, model, explain and teach supporting classroom activities. Reflecting on these visits, John commented:

> John (p. 14, 338-342): I think teachers were happy if I wrote the lesson and I turned up and led the lesson. They were more than happy to have me in the classroom doing that.

In this capacity, John acts as leader for other teachers who may lack the knowledge and skills to implement geospatial technologies in their teaching. John's design and subsequent teaching of activities that align geography content (CK), geography pedagogy (PK) and technology (TK) are a model that teachers can later emulate in their own teaching. John's reflections reveal how external specialist teachers, when invited into the geography classroom, can be an enabling contextual condition for teachers' uptake of GST.

Other external stakeholders, such as professional teacher associations, GIS developers and textbook publishers, were also identified as meso context conditions. Four early adopters (Melissa, Eric, Russell and Elizabeth) commented on the role of their respective state geography teachers' associations (GTA) in supporting teachers to implement geospatial technologies. Melissa and Russell credited the Geography Teachers' Association of Victoria (GTAV) for providing effective opportunities for teacher professional learning and resources to encourage teachers to adopt GST:

> Russell (p. 28, 676-678): There's a very strong thread of it [GST] at the GTAV conference. There's been a lot of PL/PD run around it which I have participated in myself.

Melissa (p. 21, 504-509): The GTAV is fantastic. They're really, really good and they've recognised that need so a lot of what they've done in the last 12-18 months, for VCE teachers in particular but open to everyone, has been to offer sessions at conferences or particular sessions on incorporating it.

Membership of professional associations, therefore, can provide early adopters with access to materials, resources and opportunities perhaps not available to non-members. Through the professional learning offered by the GTAV, for example, Melissa and Russell have been able to increase their knowledge for implementing GST in the classroom. The GTAV is a valuable mechanism through which Melissa and Russell develop their TPACK for teaching with GST.

Sarah considered being able to see how another teacher used geospatial technologies in her teaching to be a valuable opportunity for her to develop her own knowledge for teaching with GST:

Sarah (p. 11, 521-536): When I was going through teaching training, I was very fortunate to have a fellow student who was trained in geography, had done a degree so he was a geographer! When he was doing his presentation, most people did history presentations for modelling a unit of work or modelling a lesson in our final unit, [but] he did a map. They did the local area. I've done that with my classes this year, being able to label where things are and students to have that lightbulb moment.

Sarah's comment suggests that initial teacher education (ITE) may be an appropriate vehicle for providing teachers with opportunities to learn about geospatial technologies and its relationship to geography content and pedagogy (TPACK). By witnessing her peer use geospatial technologies in the ITE environment, Sarah was able to adapt the activity for use in her future classroom. The modelling of the activity by her peer therefore enhanced Sarah's own TPACK for teaching with GST.

Melissa mentioned that geography textbook publishers also supported her ability and capacity to implement GST in the classroom:

> Melissa (p. 7-8, 168-175): We've had an argument for a number of years here in terms of whether or not the kids should have an atlas on their book list. Going back about five years ago. We've persisted with it in terms of them understanding basic concepts of maps plus the fact that the atlases, the companies, have all made a really big effort to make really good atlases that have lots of extra support material.

The provision of support material by publishers of education textbooks, particularly CD-ROM and web-based resources, support Melissa in her GST-enhanced teaching. Students in Melissa's class access datasets provided by textbook publishers for analysis using GST applications. Melissa's selection of these resources for use in class is an expression of her understanding of how geospatial datasets can be used for teaching geography content and skills to her students (TCK/TPK/TPACK). These textbooks resources act as a context enabler for Melissa but may be an unknown or under-appreciated enabler for some teachers who lack Melissa's awareness of these materials.

7.6.2 Challenges and Opportunities for Technology Implementation in Schools

Consistent with the survey findings, two early adopters identified cost of technology (cost of geospatial technology applications and student devices for Bring Your Own Device policies) as barriers to their implementation of GST in the geography classroom. Liam described the impact of costly subscriptions to web-based GST applications on student learning:

> Liam (p. 18-19, 512-519): We used Scribble Maps. They could annotate the map and it was really good. The next step is you've got to have an account and you've got to pay for it so they couldn't save any of their work. So it was basically just doing some work and then losing it straight after. And that's a massive drawback with a platform like that because the kids, they've got really excited but they've got nothing to show for it at the end.

The cost of a subscription to Scribble Maps constrains Liam's ability to use the application to enhance student learning in the classroom. The students' inability to save their work ensures Liam has little opportunity to assess their progress or build on this work in subsequent lessons. While Liam believed Scribble Maps was valuable in engaging students, he was reluctant to use Scribble Maps because of this limitation. Liam's decision demonstrates his TPK; that is, his understanding of the affordances of the technology for teaching and learning purposes. The limitations of Scribble Maps make the technology inappropriate for teaching geography concepts and ideas in Liam's classroom.

Sarah also spoke to the constraints she experienced in using GST applications that required a subscription. Sarah reflected on how she wanted to use Esri's StoryMaps application with her Year 7 students. The web-based application, while free to use online, requires a paid subscription to save students' work in private accounts. As a consequence of school-level policies that require Sarah to protect student privacy, Sarah chose not to use the application despite the educational benefits she perceived:

Sarah (p. 15, 720-730): I would have loved this year to do their water hazards assignment using geospatial technologies and using the Storytelling program to do their projects so they could present it like that and do a talk to accompany it. But, obviously, with the privacy issues, there'd be no way. I'd be in so much trouble if I decided to risk it and use the public version. I know there would be parents who would be unhappy with me and the senior staff would have a field day.

Sarah's appreciation of the school policies related to student privacy means that she chooses resources that will allow her to work within the policy guidelines. As such, she experiences limitations in her ability to select geospatial technologies that best teach geography content to her students; that is, Sarah is constrained from enacting her TPACK by the school privacy policy.

Mirroring national (and international) moves towards BYOD/T (Bring Your Own Device/Technology) polices whereby students and their families provide technology for students to use in the classroom, many of the early adopters in this study teach in schools with active BYOD policies (Elizabeth, Melissa, Sarah, Georgia and Russell). While these policies were generally found to enable teachers' use of GST, Sarah and Liam both raised concerns about the equity of these policies and their implications for technology use in the classroom. Sarah, for example, commented on how the non-compulsory BYOD policy at her school had implications for how students felt about the use of technology in the classroom:

Sarah (p. 7, 329-336): I've noticed some of my Grade 7 students, even though they're not in the BYOD program, they have started to bring laptops and iPads in particular to class and you see other students who clearly don't own an iPad or have access to technology at home getting really upset and jealous because students have a device.

Indeed, equity issues were a major concern for Sarah. The optional BYOD policy at her school results in a division between those students who can afford to bring devices to school and those students who have limited technology access. Reflecting the schools ICSEA index value, the cost of devices for the families of Sarah's students is significant and has implications for Sarah's planning and teaching:

Sarah (p. 7, 345-349): It's not a compulsory purchase. It's purely optional. Teachers still need to ensure access for all. However, it's relying on the parent to buy the device for their son. For some, it's just too hard and too expensive.

The implications of the cost of technology is that Sarah needs to plan opportunities for students to use the school's shared computer rooms. Sarah's school has few dedicated computer rooms and Sarah struggles to gain continuity of access to the rooms. As such, Sarah is limited in her ability to use GST both for 'in-time' teaching and units of work which require continuous access to technology. Sarah is restricted in her enactment of TPACK in her geography lessons as a result of technology access barriers.

Despite some clear implications for student equity, early adopters generally perceived BYOD policies to be an enabler of their use of geospatial technologies for geography teaching. For Liam, his school's adoption of a BYOD policy gives him license to pursue GST, particularly Google Maps, in his teaching:

Liam (p. 4, 88-94): The school is moving towards a BYOD set up in the junior years from next year and that will sort of trickle along through the years over the next few years until we're a full on BYOD school supported by

Google Apps for Education. So Google Maps will become a real driver for us in geography.

The BYOD program at Liam's school opens up opportunities for Liam to further embed GST into his practice. By having individual student access to the technology, Liam understands that he will be able to make more use of Google Maps as a pedagogical tool for teaching geography (TCK/TPK/TPACK).

Georgia also spoke of the value of BYOD in increasing her opportunities to use geospatial technologies. Georgia commented that GST "is there on student devices" (p. 6, 147-148) and, as a result, there is greater impetus for her to make use of the technology in her teaching.

Elizabeth acknowledged that her school's long running BYOD policy (and the reliable Internet connection that supports it) has an influence on the way she teaches geography:

> Elizabeth (p. 5, 108-116): Our school is very well positioned for ICT. We've had the one-to-one laptop program for nearly six years now so every student in the school from Year 7 upwards has a laptop. I do think that I forget how lucky I am until I talk to other teachers who tell me that they don't have a very good Internet network. Like all networks, it has its days but the majority of the time it's a pretty flawless system. That makes a huge difference to teaching, to your pedagogy, to how you go about things because you've got that reliability.

Elizabeth's comments reflect her understanding of how technology alters geography pedagogy (TPK). The BYOD policy enables her to make full use of technology in the classroom and she has learned to adapt her teaching practice in response to the technology availability. The "reliability" of the system gives Elizabeth license to develop learning tasks that require the use of GST for students to successfully demonstrate their learning.

Although a number of the early adopters perceived BYOD policies to be enablers of their GST teaching, policies that permit students to bring a range of device types to school also present challenges for teaching. The compatibility of student devices with specific geospatial technology applications means that teachers need to be aware of the particular affordances and/or limitations related to students' accessing GST applications on their devices. As Liam mentioned:

> Liam (p. 20, 529-541): It's really about the access that kids can have so it's first going to be around their devices, the capabilities of different devices is going to allow them to do different things. Google is really useful and can be really powerful but if you've got a tablet, like an iPad, it's not going to work. It will only work on a laptop or, effectively, it's going to be really hard on an iPad. Whereas Scribble Maps works really well on an iPad but it's not that great on a desktop yet. So the device has a big sway over it and how you access it with that device.

Liam's comments reflect his knowledge of the best ways to present geographical information using geospatial technology (TCK). Liam knows that some technologies will present certain geographical information better than others.

Sarah acknowledged that the different capabilities and affordances of student devices were a strain on her knowledge for teaching with technology: "[It] can be very frustrating sometimes because the devices are all different" (p. 7, 323-326). To make the most of opportunities presented by BYOD, teachers need to be familiar with the range of technologies students bring to school and must be able to troubleshoot any issues with that technology as they arise within the classroom environment.

Effective use of BYOD devices in the classroom, therefore, necessitates that teachers have sufficient technology knowledge (TK) about a variety of operating systems and processes.

An ICT policy at Elizabeth's school restricts the downloading and installation of software onto student laptops: "If they [school administration] have to load it on to our computers, they're not interested. If it's not web-based, they're not interested" (Elizabeth, p. 11, 265-267). As a result, Elizabeth is able to select only those geospatial technology applications that are accessible online. While Elizabeth is knowledgeable about online GST applications (particularly Google MyMaps), the restriction on installing software means she is unable to use the professional GIS software, ArcGIS, for which she has completed training.

While constrained in her ability to teach with ArcGIS, Elizabeth admitted that the complexity of the professional GIS software presented significant challenges when using it for teaching. Reflecting on her experiences of teaching with the software, Elizabeth stated:

> Elizabeth (p. 9-10, 218-229): I did the "Ok, we're going to use ArcGIS and blah blah." The first thing I would say was what I did when I taught geography then was that I taught a software package. I spent, I think this would be fair to say, 90% of my classroom time when I was doing that. Maybe 90's a bit high but a large proportion of my time, teaching the kids how to use this technology, how to manipulate it – now click here, now click there, now do this, now do that – and then in meantime you've got no actual geographical analysis happening. Yes, you can do analysis but that, at the end, became such a small part of the time that was spent in trying to make this work and make that work. Make it look pretty!

Elizabeth’s comment demonstrates her appreciation of how technology can affect student learning. Although the objective of Elizabeth’s learning activity was to facilitate students’ geographical analysis, the complexity of ArcGIS was a hindrance to Elizabeth’s ability to exercise effective geography pedagogy. Elizabeth’s reflection highlights the appreciation she has gained for planning and teaching GST-enhanced activities that allow for meaningful geography teaching and learning.

Other early adopters expressed similar concerns about the complexity of professional GIS and its effect on geography teaching and learning. Russell suggested that the complexity of GIS impinged on his ability to develop students’ learning in geography:

> Russell (p. 20, 484-492): The barriers have changed. So for us with GIS, it used to be the accessibility, the cost of the platform and the data. The complexity hasn’t necessarily gone away totally. And you can’t engage kids for long enough over a long enough period of time to say sequentially and cumulatively build their knowledge in a GIS platform as complex as QGIS, MapInfo or ArcGIS even, whatever really.

For Russell, the complexity of GIS software limits the pedagogical application of the software. He believes that the complexity constrains students from building their geography knowledge.

John reflected on how the complexity of GIS also affects teachers’ inclinations to adopt the technology. John recalled a time when he organised ArcGIS training for teachers in NSW:

> John (p. 8, 183-197): I got some funding from somewhere for [ArcGIS training] and we signed up a few teachers to do this course and it was good. Except it was kind of clear from the start that for most of those teachers, some of

whom were older, they were interested in GIS because it was in the geography syllabus but their general assessment in the evaluation was: look, I'm glad I did it because now I know what GIS is and how you can use it and how you can apply it and I can teach that to students but I won't be trying to use it in my own classroom in terms of collecting and managing data. It was more in terms of teaching what GIS was in the end for some of those teachers.

John's experience, and also Elizabeth's and Russell's reflections on the limitations of professional GIS, are commensurable with findings from previous research studies which have identified GIS complexity as a major barrier to GST implementation in schools (Yap et al., 2008). The complexity of GIS constrains teachers' ability to utilise the technology as a pedagogical tool for teaching geography.

Overall, early adopters identified a variety of contextual challenges (barriers) and opportunities (enablers) for technology implementation in schools. These contextual conditions have implications for the future direction of education policy and pedagogical practice in geography education. These implications are discussed in depth in Chapter 10.

7.6.3 Teacher Education

Liam and Melissa noted that opportunities for teachers to learn about geospatial technologies are relatively limited. Liam commented on how the use of geospatial technologies was not commonplace during his geography degree and how this has wider implications for teachers' knowledge about GST:

Liam (p. 2-3, 48-53): When I did my geography degree, I finished in 1997, there wasn't really such a thing as geospatial technology, definitely not the way it is now. So for many older teachers, one of the barriers will be that they don't even know what it is from their university days.

The swift development and diffusion of geospatial technology has made GST a highly utilised tool for geography teaching and learning in Higher Education (HE). As Liam's comment reflects, teachers who completed their geography education prior to the rapid uptake of geospatial technology in HE may be unaware of the various technologies and their relationship to the discipline. These teachers, therefore, will need to have in-service support for learning about the technologies.

Providers of professional learning opportunities need to be cognisant, however, that PL must be 'pitched' at a level appropriate for teachers with limited knowledge of GST and its relationship to geography content and pedagogy. Melissa's experience attending a professional learning session about GST indicates that some providers may be inadvertently discouraging teachers from adopting the technology:

> Melissa (p. 14, 335-340): I think people feel like they're amazing tools and I think after we [Melissa and her colleague] did our conference presentation, one of the people who followed on from us was really, really on top of it but it was kind of scary because I thought, gosh, if this is how he's doing it, how am I doing it? So that could almost work the opposite and put me off.

Although Melissa self-identified as highly knowledgeable and confident in her GST-enhanced geography teaching, the professional learning experience intimidated her. Melissa negatively compared her teaching to that of the presenter, questioning the quality of her geography teaching and learning activities. Effective professional learning, which serves to encourage GST implementation, must be designed to be accessible, meaningful and useful for all teachers, regardless of their prior knowledge and experience with the technology. Inappropriate professional learning has the potential to impede teachers' TPACK development.

7.6.4 Whole School Geography Education Barriers

Early adopters also perceived a range of whole-school barriers to geography education in their teaching contexts. Four early adopters (Liam, Eric, Georgia and Elizabeth) commented on low levels of student retention in post-compulsory geography subjects (i.e. senior secondary study). Liam summed up the problem:

> Liam (p. 7-8, 163-167; 231-235): The NSW syllabus also offers in Year 9 and 10 a geography elective. But we never run it at the school. It's been offered every year but it's never been picked up by the students… We're not running a geography class in Year 11 this year. We haven't had enough people select it and it's looking the same again next year. So that's two years in a row we won't have a geography class when [the current] Year 12 leaves.

Liam's comment typifies a national trend towards poor student retention in post-compulsory geography subjects (Erebus International, 2008). Few students selecting senior secondary geography courses means that some schools cannot justify the expense of teacher staffing and resourcing associated with running the subject. Poor student retention in geography has the potential to lead to an inadequately prepared spatial workforce, which is of critical concern to Australia's continued economic prosperity (Lawrence, 2011).

Some early adopters perceived the status of geography in schools to be a significant barrier to students' achievement and interest in the subject, perhaps contributing to poor student retention in geography. Liam argued:

Liam (p. 8-9, 247-261): I see geography has been kind of a light [subject], placed on a lower rung of importance. Kids enjoy the subject but they don't see it connecting or being that important compared to science and maths or English. So, they're the big jewel in the crown, those three subjects. History usually goes very well at our school. And then the lower subjects – geography, religious education and the PDHPE [physical education], non-academic, which is frustrating because I'm trying to lift not only the profile of the subject but also the quality of the work produced and sometimes find it almost like fighting against itself when I'm trying to get quality there, so improved writing and academic rigour, with students who aren't up to that level.

Liam's statement reflects the poor status of geography in some schools. As described by Hutchinson (2006), geography has had to compete with other school subjects for its place within the curriculum. Liam's comments reflect his understanding of how to improve student learning; he understands that increased academic rigour and writing skills are what are needed to bring his students up to the required standard. Liam reports being constrained in his attempts to exercise his knowledge for teaching by a school culture that categorises geography as a 'lesser' subject compared to Maths and English.

Sarah reflected on how decisions made by school administrators at her school have served to marginalise geography and curtail student interest and learning in the subject:

Sarah (p. 9, 420-426; 439-443): The way I'm teaching this year is that my Head of Department has dictated that we do a general overview of geography in the first couple of weeks. Doing basic things like BOLTSS [Border, Orientation, Legend, Title, Scale and Source, the key features of a map].

They need to be over BOLTSS but it took a lot longer than expected because of a lot of interruptions in Term one… then we launched into Ancient Rome. Then we came back to geography with the Water in the World [unit]. It's like, what's the point of all this? I've seen my students start to disconnect, definitely disengage.

Sarah's comment reflects how decisions about the sequencing of subject content in the multi-disciplinary Humanities subject has the capacity to influence student motivation and interest in geography. Sarah's Head of Department's choice to sequence learning by topic – that is, a geography unit followed by a history unit followed by a geography unit – served to limits students' ability to make connections with geography content and skills. This decision also restricted Sarah in her capacity to act upon her understanding of what makes for effective student learning in geography (PCK). Sarah appreciates that the disjointed learning sequence she is required to teach to is not an effective way to teach geography to her students.

Alternatively, Liam identified how administrative decisions about the scheduling of teachers actually enabled more geography teaching in his schools to be taught by geography specialists:

Liam (p. 7-8, 213-215; 227-230): [when describing the timetabling of teachers and classes] We're trying to get as many students to have a geography and history trained teacher teaching them those subjects as possible… Depending on the loads, the lines, who's available to teach and that sort of thing. So it's been flexible the way we allocate it. That school administration sort of stuff.

By scheduling teachers like Liam, who hold a geography teaching specialisation in geography classrooms, Liam's school administrators demonstrate a belief that teachers with background training and knowledge in geography are best prepared to teach the subject to students. That is, the school administrators accept that geography teachers require specialised knowledge of geography content and pedagogies that support geography learning (CK/PK/PCK). Liam's teaching load provides opportunities for him to exercise his specialised CK/PK/PCK in classrooms by specifically engaging in geography education.

7.6.5 Summary of Meso Context Conditions

A variety of meso context conditions were found to both enable and constrain the early adopters' implementation of GST in the classroom and their TPACK (Figure 7.5). Professional teaching networks, collaborative planning opportunities and Bring Your Own Device policies were generally found to be key meso level enablers of the early adopters' GST practice. A lack of adequate teacher training (ITE and in-service), the cost of GST applications and school-level ICT policies which tended to restrict access to some applications served to constrain the early adopters' practice and ability to enact their TPACK. The barriers remain consistent with those reported in previous research indicating that, despite the inclusion of geospatial technologies within *Australian Curriculum: Geography*, limited teacher training opportunities and the financial cost of the technologies are still persistent challenges for teachers wanting to adopt GST (Kinniburgh, 2008; Wheeler et al., 2010).

Meso context conditions reflect school-wide decisions made by school administration/leaders. While teachers who are employed in leadership positions may have some level of autonomy over how school-wide policies are enacted and, therefore, could work to create the context conditions that support GST use in their school, other teachers who are not in leadership positions may find themselves unable to influence policy decisions. These teachers must find a way to use geospatial technologies within the boundaries of the policies and decisions made by school administrators.

Importantly, however, there do also appear to be opportunities for teachers to exercise some agency to shape the meso context conditions in which they operate. A number of the early adopters spoke about the value they perceived in joining a professional teachers’ association and how these associations provided resources and professional learning opportunities not regularly available in schools. The support of the GTAV, for example, was particularly useful for Melissa and Russell in driving them to embed geospatial technologies deeply into their geography teaching practice. The reflections of the early adopters indicate that teachers can exercise some agency in seeking out opportunities to enhance their own TPACK and GST teaching practice within the myriad of meso context conditions.

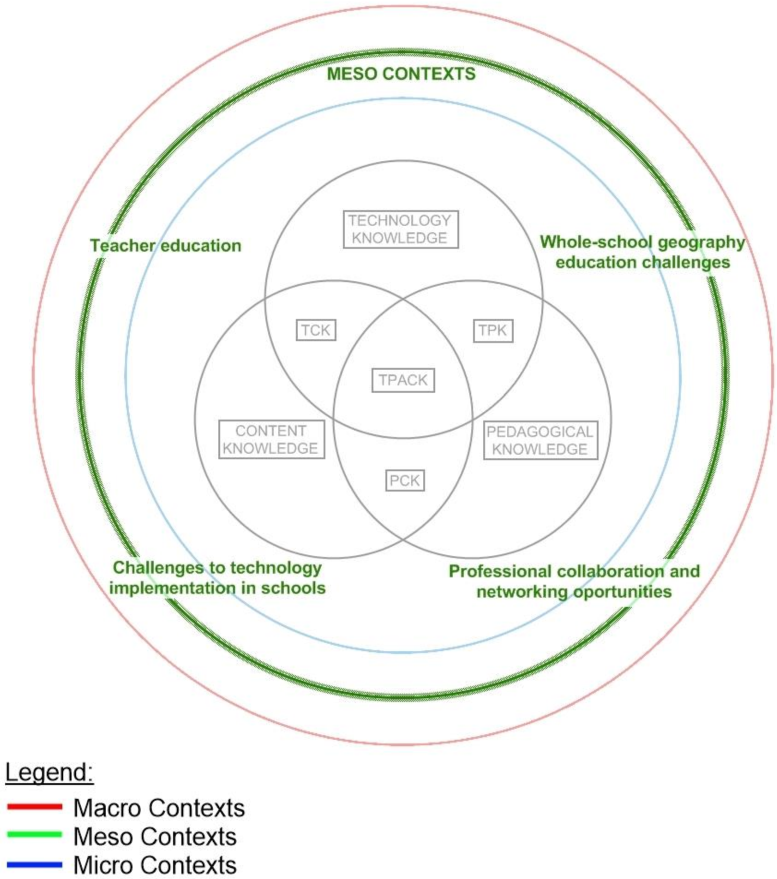


Figure 7.5. Influencing meso context conditions.

7.7 Micro Context Conditions

Thematic analysis of interview data using Braun and Clarke's (2006) techniques resulted in the generation of codes representing 11 micro level context conditions. Collating and visually mapping the codes (Figure 7.6) revealed three overarching themes. These themes were '*classroom technology conditions', 'classroom operational conditions'* and *'appropriateness of teaching resources.'*

7.7.1 Classroom Technology Conditions

Early adopters identified conditions that occur in their classrooms that influenced their decisions about implementing GST. A limited ability to access technology for specific in-class teaching activities was a particular issue raised twice by Sarah:

> Sarah (p. 7, 319-324): We have about six computer labs equipped with all sorts of different computers so it's obviously PC orientated. I find it very difficult sometimes to get booked into a computer lab.
>
> Sarah (p. 13, 632-340): The big thing is access to technology and lots of schools just don't have the resources or the numbers of computers that are necessary in order to guarantee lesson after lesson so you can follow a sequence. It's a big ask, in a small school in particular. Like in [previous school], to have the ICT every lesson because you've got to share it amongst the rest of the classes.

Sarah's comments highlight how a lack of ICT provision in some school classrooms has an effect on teachers' ability to appropriately design and teach a learning sequence in geography. While the school does provide for technology access at the whole-school (meso) level, having to share these resources with other teachers impacts on the in-class (micro) conditions for learning.

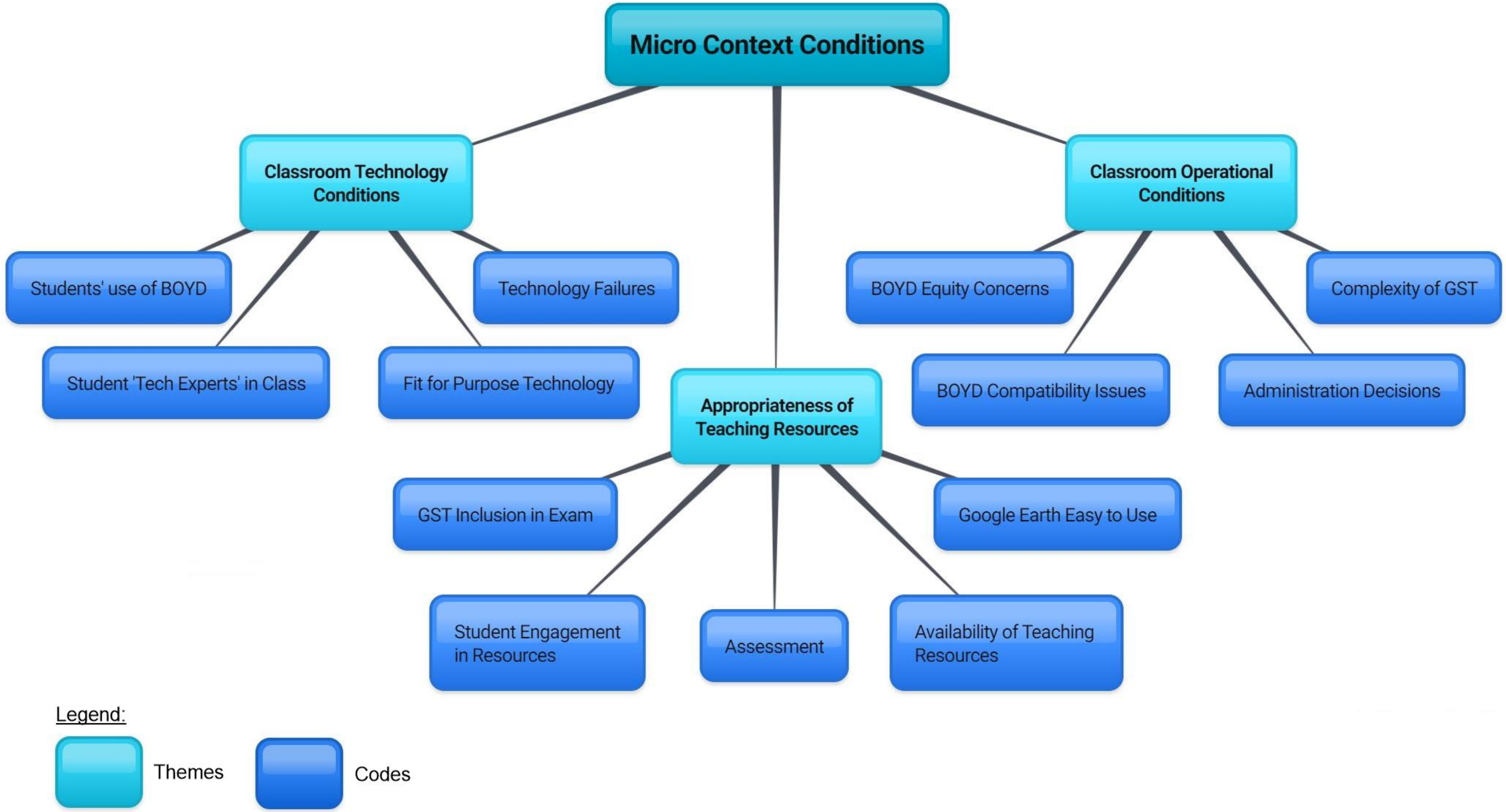


Figure 7.6. Mind-map: Micro context conditions.

The limitations posed by Sarah's in-class technology conditions become clearer when her conditions are compared with those of Eric. As identified in Chapter 6, Eric's school is highly resourced and students are able to access technology for each subject.

> Eric (p. 4-5, 94-100): In geography, we have computers in our room. Our largest class size would be 24 and each of our rooms have a minimum of 13 computers in them. We'd probably get rid of them with the advent of BYOD but you just need a bit of extra grunt, and I think, screen size, particularly for ArcMap [GIS].

Eric's comments not only create a point of comparison between Sarah's under-resourced context and Eric's well-resourced context, but also identifies how the technology used for teaching with GST must be fit-for-purpose. The general level of availability of technology in a school may still not able teachers to teach with GST. Limitations of screen size, bandwidth and device capabilities, for example, can affect teachers' ability to act on their TPACK for teaching with GST in their classroom context.

John also underscored the importance of fit-for-purpose technology when reflecting on the challenges he faced in developing educational resources for students using laptops provided under the DER policy in NSW:

> John (p. 27, 648-658): One of the issues with the DER laptops… they all had these small laptops which there were issues with and one of the things we found were that when we tried to get them to do Google Earth activities on those laptops was just the size of the screen and the manipulation of things made it a bit awkward for some kids. There were things that didn't seem to display properly.

The smaller screen sizes of the DER laptops meant that the activities John planned were not as successful as they might have been on computers with larger screens. John's expression of his TPACK for planning and teaching GST-enhanced geography lessons was constrained by the limitations of the screen sizes.

A common theme that emerged from early adopters' responses was their understanding of the inevitability of technology failures during teaching. Eric summarised the effect of technology failures on what happens in the classroom:

> Eric (p. 21, 495-503): Look, sometimes technical difficulties will hold things back but I think generally we've hopped in and had a go. There are frustrations at time because of the way data is stored. Or if your system is down. You plan what you see is a pretty tight lesson and you want to go bang, bang, bang, proper teaching activity, next activity and then the server is down and it jigs your own lesson.

Despite Eric's school being well resourced for learning with technology, his reflections on the impact of technology failures on his teaching are not dissimilar to those of Liam who teaches in a school with fewer technology resources:

> Liam (p. 11, 272-276): Every now and again, with 30 kids trying to log on all at once, the Wi-Fi access points can be overloaded and things like that. So login times can be slower, downloading things and research time can be a bit problematic.

Eric and Liam's reflections indicate that the number of computers/devices/technologies in the classroom does not make teachers immune to technology failures during their lessons. Technology failures will inevitably constrain teachers' ability to utilise technology for teaching in the classroom.

Finally, Eric, Elizabeth and Russell spoke about the ease of use of particular geospatial technologies, such as the Google technologies. As Eric argued, "Google

Earth is pretty intuitive" (p. 25, 620) and, therefore, the ease with which students can pick up the skills and understandings needed to use Google Earth made it an effective pedagogical tool for geography teaching. Elizabeth particularly contrasted students' ease of use of Google MyMaps with that of ArcGIS:

> Elizabeth (p. 12, 274-291): Fast forward 15 years, you've got Google Earth [which] is pretty straight forward to use…. My favourite [platform] is Google MyMaps because you can do some of that layering effect and you can do some of that styling. It is simplistic, there's no doubt about it, but you can come back to, right, what are we trying to achieve here with the students? What is our goal? What do we want them to be able to identify, to learn? When you're spending three weeks to get a result [with ArcGIS] that you could probably get in two lessons using Google, you go 'yeah, it's kind of a bit of a no-brainer.' I think that's part of the reason why a lot of teachers in the past just didn't embrace [ArcGIS] because you had the ones that really got on board with it and they were great, but anyone else who didn't get on board with it, they went "ugh, too hard, won't be bothered." Whereas, I think a lot of the other stuff now, it is much easier for people to learn. I can teach kids in a lesson how to set up a Google MyMap and have a completed map. Whereas, that wouldn't have been the case years ago.

Similarly, Russell also identified students' ease of use of Google Earth and how it has influenced his decisions when teaching:

> Russell (p. 21-22, 517-527): What holds you back [from using professional GIS]? It's still the amount of time and the complexity. To hold kids' attention and get them to see it's worthwhile getting in to a level of detail you need to make something happen. That's where Google Earth and importing something from Excel or whatever, you can achieve it inside a week from

start to finish. A week of geography teaching time – which isn't necessarily a lot – you can have them doing it. It's not something you can necessarily do with a lot of the platforms out there.

In their reflections, Elizabeth and Russell both demonstrate their appreciation of how the less-complex Google technologies work to provide the in-class conditions that allow them to enact their TPACK. Both teachers make conscious choices to use Google technologies (instead of professional GIS) because the technologies more easily serve their needs for teaching geography. The decisions that Elizabeth and Russell make about using Google technologies in their specific contexts are demonstrative of their technological, pedagogical and content knowledge.

7.7.2 Classroom Operational Conditions

Five of the early adopters spoke specifically about general operational requirements in schools (such as, instructional time, classroom layout and staffing) as both constraining and enabling their GST teaching. Three of the early adopters (Sarah, Russell and Melissa) mentioned constraints related to limited instructional time in class. Sarah identified that the many demands of teaching (teaching, assessment and reporting) and her belief that limited instructional time for geography, compound these demands:

Sarah (p. 8, 396-398): I've become very frustrated because we just don't have time to do everything that we want to do… Time is a big factor when you're teaching. The fact is we've only got three hours a week to be able to get them through the content and you do need to allow time for them to do the assessment which informs part of their report.

Melissa agreed:

Melissa (p. 15, 356-366): I think the other thing is that teachers feel they lack time. So, for example, we get two 80 minute periods a week – we do a fortnightly cycle – for most of our junior school classes so inevitably one of those goes missing every second week. So time is limited anyway so if you're teaching students a basic geographic concept, the ability to add spatial technologies to that? If you've got to teach that skills and the technology as well, as lot of people are going to say 'just can't do it

Russell expanded on Melissa's argument:

Russell (p. 20, 474-478): I think we're always going to have that trade-off between the complexity and the lead-time it takes to get kids to the point where they can use the higher level stuff. It's a trade-off between the amount of time. It's a cost benefit analysis, that's what it is. The cost in time.

In their comments, Sarah, Melissa and Russell all demonstrate an awareness of the many competing challenges of classroom teaching. Their responses demonstrate how, in addressing these challenges and making decisions about what they teach and how they teach, the teachers utilise their knowledge of the curriculum (CK), their understanding of the time it takes students to learn the content and skills to use GST (PK/PCK), and the conditions that govern how much instructional time is provided for geography teaching in their respective schools.

Liam described how the layout of his classroom challenges his ability to exercise effective pedagogy when using technology (TPK):

Liam (p. 4-5, 99-112): In a short space of time, I needed to do the explicit teaching but then get them actually active and working because the [open learning] class space like that isn't very conducive to explicit teaching. You've got to do your explicit teaching in class. I'm still learning how to use the space to get the most out of it. The explicit teaching should have been done in the classroom setting, I think, or some sort of confined space so that when they hit the open learning in the next lesson then they're kind of more set up ready to get started on the work and do the work and make the most of the available time we've got with the laptops.

Although the open-learning spaces at Liam's school were designed to increase students' access and use of technology, Liam's reflection illustrates that the physical space challenges his pedagogy and how he uses technology in his teaching. The challenges of using the open-learning space signal to Liam a need to adapt his pedagogy, particularly the timing and location of his explicit teaching episodes, to allow students to be better prepared for undertaking the technology activities. In expressing this thinking, Liam is explicitly communicating his PK and TPK.

Finally, John underscored how in-class conditions relating to teacher/adult supervision may be an enabler of teachers' use of GST in the classroom:

> John (p. 133, 812-819): It becomes harder when you hand over control to the kids [to use GST]. It's good to have a couple of adults to move around the room with the kids who have difficulty with computers.

In John's visits to schools to teach his materials to students, he acts as 'teacher' in addition to the students' regular classroom teacher. Thus, John is able to capitalise on having a second supervising teacher in the classroom when using GST. John's comments indicate that sole teachers in the classroom may have difficulties managing students' GST use alone.

7.7.3 Appropriateness of Teaching Resources.

Consistent with findings from the research (Hong, 2014), a lack of appropriate teaching resources to support the use of GST in class was an issue also raised by five of the early adopters in this study. Georgia reported finding some of the 'Street View' images on Google Maps too "out of date" (p. 5, 106) for her to use in the classroom. Eric reported feeling "embarrassed" (p. 19, 457) to ask parents to buy textbooks because “whenever a textbook is written, it’s out of date for us” (p. 15, 369-370). Instead, Eric reported using Internet resources to collect up-to-date geographical information. Melissa, on the other hand, described why many video tutorials about using GST were inappropriate for her class:

> Melissa (p. 14, 344-346): I know that even for mine, there’s not a lot of secondary school friendly tutorials for how to use things. A lot of it’s tertiary based or business based.

In acknowledging and justifying the inappropriateness of many of the existing resources for teaching geography, the early adopters demonstrate their understanding of geography content, pedagogy and the best way to use technology in their teaching. From the early adopters’ comments, it is clear that this in-class, micro context condition influences the decisions teachers make about selecting and utilising resources in their classroom.

7.7.4 Summary of Micro Context Conditions

The reflections of the early adopters indicate that there are numerous micro context conditions which they must mitigate when using geospatial technologies for in-class learning (Figure 7.7). The effect of classroom technology conditions on teachers’ ability to act on their TPACK in teaching with GST was a common theme amongst the early adopters. This continues to mirror earlier research findings that point to barriers to GST adoption based on limited technology availability in classrooms (Baker & Kerski, 2014). In this study, early adopters specifically perceived *fit-for-purpose* technology to be important for producing the conditions to support student learning in geography. This perhaps marks a shift away from concerns about the availability of technology generally to a focus on considering those technologies that are best suited to GST-enhanced teaching and learning.

A further important finding of this study is that the provision of technology at the whole school level does not make teachers immune to the challenges of technology failure nor does the mere presence of technology mean that teachers can actually use that technology with every GST application. While a key focus of previous research has been to identify barriers related to technology availability (Milson & Kerski, 2012; Nielsen, Oberle & Sugumaran, 2011), the findings from this study also draw attention to the necessity for teachers to be resilient to technology failure and to make use of their TPACK knowledge in understanding how GST can be embedded within geography content and pedagogy in teaching.

It is within the micro context conditions that the early adopters appeared to exercise their TPACK most often; that is, in their reflections, the early adopters spoke specifically to their TPACK and the in-class conditions they had to consider when selecting appropriate content, pedagogy and technology for the tasks they designed. This indicates that the early adopters, drawing on their strong technological, pedagogical and content knowledge, were able to circumvent many of the micro context conditions that may constrain other teachers in their GST implementation. The presence of early adopters in schools may, therefore, be critical in working to reduce the micro context conditions that constrain yet-to-adopt colleagues.

Teachers' knowledge (geography knowledge, pedagogical knowledge, or technology knowledge) was not perceived to be barrier to their GST adoption. Indeed, none of the early adopters indicated any challenges to successful GST adoption relating to their knowledge, despite their varying levels of past experience with the technologies. This result stands in contrast to those of the existing literature which continues to cite poor teacher knowledge of GST as an impediment to teacher adoption (Hammond et al., 2018; Mitchell, Roy, Fritch & Wood, 2018). This study provides some evidence, therefore, that early adopters of GST consider a range of other micro conditions to be more influential on their GST teaching practices.

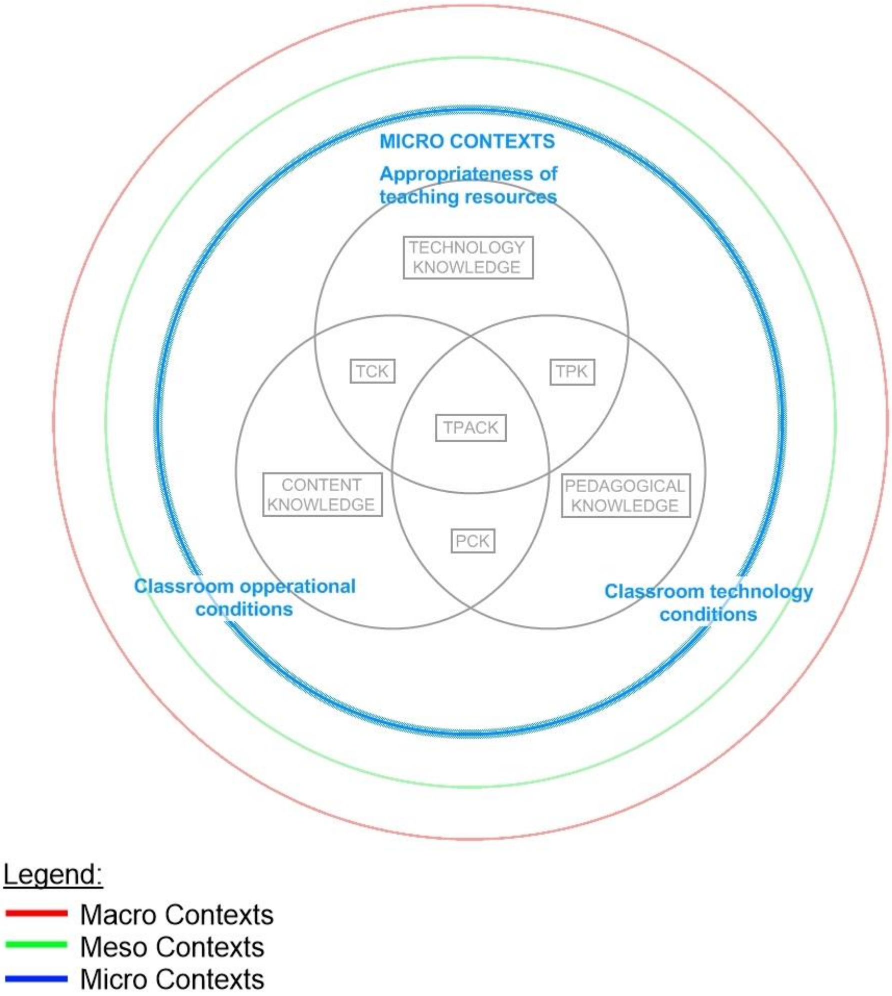


Figure 7.7. Influencing micro context conditions

7.8 Contributions to Research Question

RQ2. How do context barriers and enablers influence early adopters' use of geospatial technologies in their geography teaching?

Analysis of the responses of the early adopters supports the contention that context matters; that is, macro, meso and micro context conditions influence, constrain and enable teachers' practice of teaching with geospatial technologies and their ability to enact their technological, pedagogical and content knowledge (TPACK). Early adopters in this study described a series of macro, meso and micro conditions that affect the decisions that they make about implementing GST, how they choose appropriate content, pedagogy and technology to support students' learning of geography and the challenges and opportunities they perceive for their future GST-enhanced practice. These context conditions are represented in Figure 7.8.

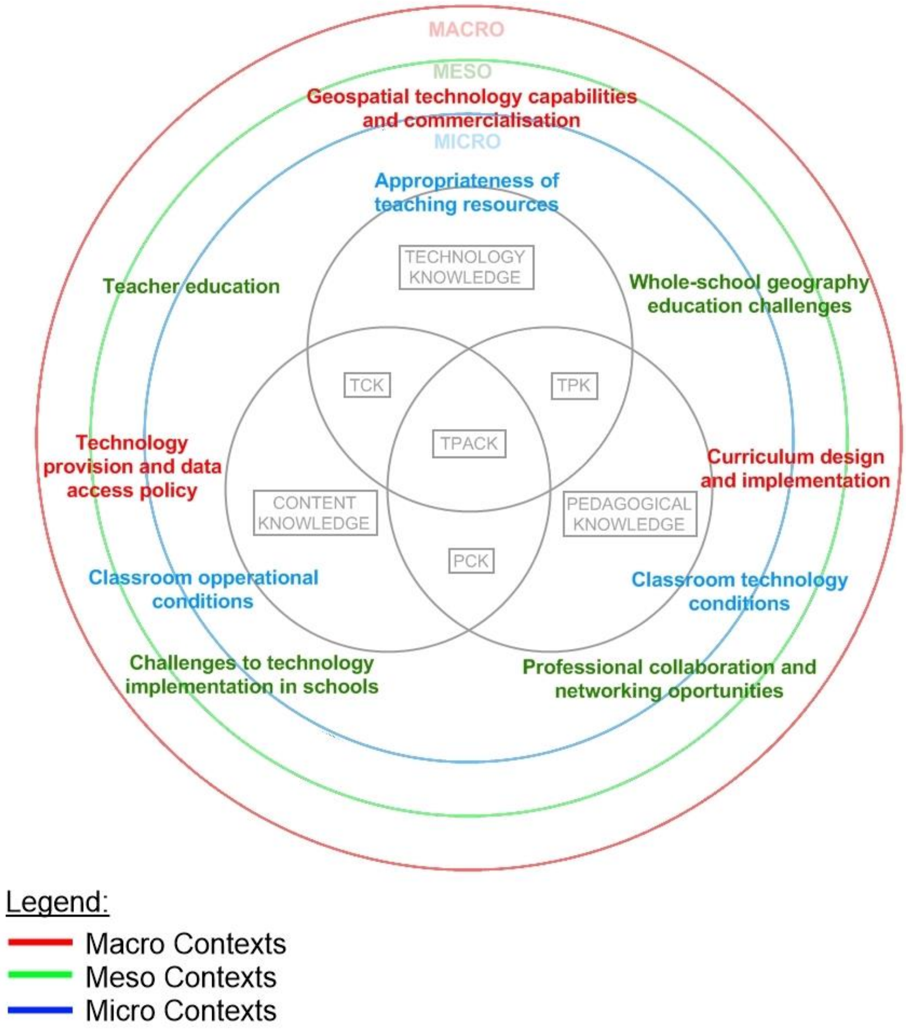


Figure 7.8. Macro, meso and micro context conditions.

Many of the context conditions found to constrain teachers' adoption of GST appear consistent with previous research (e.g. Bednarz, 2004; Kerski, 2003; Wheeler et al., 2010), the continued presence of these barriers does appear to still constrain teachers' GST adoption at the macro, meso and micro levels. This study has found, however, that there exists a number of enablers of GST-enhanced teaching practices that are cause for optimism for the increased use of these technologies in the classroom. In this regard, the key findings from this chapter are:

- Macro level context conditions have emerged in recent years in line with technological advances and an increased government-led commitment to public data sharing. The emergence of these conditions signals positive opportunities for more teachers to adopt GST into the future.
- The relevance of GST to the Australian Curriculum significantly influences teachers' inclinations to adopt GST. While *Australian Curriculum: Geography* is a strong positive influence on teachers' adoption decisions, a lack of curriculum relevance in some senior secondary contexts, particularly in NSW, will need to be addressed for GST to enter the pedagogical repertoire of these senior school teachers.
- While macro conditions can play a critical role in encouraging teachers to adopt GST, barriers to adoption still persist at meso and micro levels which do constrain early adopters' practices. The insights offered by the early adopters in this study illuminate ways of mitigating some of the challenges of context conditions.

7.9 Chapter Conclusion

This chapter has provided qualitative evidence to support the contention that macro, meso and micro context conditions influence, constrain and enable teachers' use of GST for geography teaching and their ability to express their TPACK. Whilst the influence of context on the TPACK of early adopters of GST is an under-theorised element of GST education research (see Truatmann and MaKinster (2010), as a notable exception), some of the meso and micro context conditions observed by teachers were found be consistent with the findings of previous research (Milson & Kerski, 2012; Nielsen, Oberle & Sugumaran, 2011). The cost of GST applications/software and technology access (specifically fit-for-purpose technology access) remain clear barriers.

The TPACK context framework advanced by Porras-Hernández and Salinas-Amescua (2013) was used in this chapter to examine the different 'levels' (macro, meso and micro) of context conditions and how these contexts enable and constrain the early adopters. The extent to which teachers have 'control' over the contexts in which they teach differs at each level. Teachers may have little control over macro context conditions, while some teachers in school leadership positions may have some autonomy in shaping meso context conditions in their schools. Consistent with existing research (Pearson & Moomaw, 2005), the teachers in this study appeared to have most autonomy when the context conditions related to their own classrooms (micro context). Barriers at this level were more readily circumvented by the early adopters.

This chapter, in responding to RQ2, demonstrates that efforts to further diffuse geospatial technologies in schools must consider macro, meso and micro context conditions for teaching. In the next chapter, Chapter Eight, early adopters' practices for teaching with GST will be explored. Specifically, the teaching artefacts provided by the early adopters are presented and analysed with a view to identifying how the early adopters act on their technological, pedagogical and content knowledge (TPACK) in using geospatial technologies to enhance their geography teaching.

Chapter 8

Early Adopters' Use of GST in Geography Teaching

8.1 Introduction

This chapter primarily responds to RQ3. How do early adopters utilise geospatial technologies to enhance their geography teaching? Drawing on evidence from the survey, semi-structured interviews and teaching artefacts provided by some of the early adopters for whom detailed examples were available, this chapter evaluates how these early adopters combine geography content, pedagogy and geospatial technologies to provide sophisticated and complex learning opportunities for their students. The work of Liam, Elizabeth, Eric and Russell represents the emerging high-level GST-enhanced geography teaching practices of early adopters teaching in Australian secondary schools. An adapted framework based on Anderson et al.'s (2001) revised version of Bloom's *Taxonomy of Educational Objectives, Volume 1: Cognitive Domain* (1956) is used to make evaluative judgements about how the early adopters utilise GST for promoting students' engagement with higher-order thinking and geography knowledge.

In evaluating the early adopters' teaching artefacts, analysis of the teachers' technological, pedagogical and content knowledge (TPACK) is also presented and, thus, this chapter also provides further insights for RQ1. What are the characteristics of early adopters of geospatial technologies in geography teaching in Australian secondary schools?

8.2 Bloom's Taxonomy of Educational Objectives

In evaluating how the teachers utilise geospatial technologies in their geography teaching, this chapter makes use of a framework derived from Anderson et al.'s (2001) revision of the *Taxonomy of Educational Objectives, Volume 1: Cognitive Domain* first published by Benjamin Bloom in 1956 (Bloom et al., 1956). Bloom's Taxonomy has been highly influential in shaping contemporary education practices, establishing a hierarchy of educational objectives which teachers can use to plan their teaching activities. In adopting action verbs from Bloom's Taxonomy, teachers can provide students with more sophisticated and complex learning opportunities (Seddon, 1978). Bloom's Taxonomy is a well utilised framework for evaluating teaching and learning in contemporary education research (see, for example, Bijsterbosch, van der Schee & Kuiper, 2017; Hopson, Simms & Knezek, 2001). Bloom's Taxonomy has been used in a range of studies about teaching and learning contexts, including language learning (Phakiti, 2018), mathematics education (Radmehr & Drake, 2018) and history education (Hanes & Stone, 2018).

The use of the Bloom's Taxonomy framework within this study was highly appropriate for analysing the emergent practices of early adopters of GST. The framework provided a means for exploring how early adopters' teaching artefacts could enable students' higher-order thinking through students' use of GST as an essential component of the task design. This framework is consistent with that used in recently published literature in GST education by Bijsterbosch, van der Schee and

Kuiper (2017) who used an adapted-Bloom's Taxonomy framework to assess the quality of geography education in the Netherlands.

Figure 8.1 is a visual representation of the framework used in this chapter to evaluate how teachers are using geospatial technologies to enhance geography teaching. This framework is adapted from Anderson et al.'s (2001) revision of Bloom's Taxonomy, which provides a clear articulation and description of what Bloom termed 'cognitive processes' (or thinking skills) with which students engage when learning. The Taxonomy is a hierarchy with less complex cognitive processes or lower-order thinking skills (such as remembering and understanding) represented at the bottom of the hierarchy, while more complex and challenging cognitive processes or higher-order thinking skills (for example, evaluating and creating) constitute the top of the hierarchy. Anderson et al.'s (2001) articulation of the Taxonomy provides a list of verbs that can be used to describe students' thinking skills at each of the levels of Bloom's hierarchy.

In Figure 8.1, the conceptual stages of Bloom's cognitive processes are represented by black bolded rectangles, while Anderson et al.'s (2001) list of associated verbs are represented by blue circles. A grey arrow represents the order of the hierarchy from lower-order thinking skills to higher-order thinking skills. Lower-order thinking skills include recognising and recalling information from memory and identifying or reciting information. Higher-order thinking skills allow for planning, producing and generating a new product which is developed through synthesising and interpreting new learnings. It is notable that 'create' appears at the apex of Bloom's adapted hierarchy, underlining how high-quality learning activities enable critical and creative representations of students' learning.

This framework is utilised to evaluate the teaching artefacts provided by early adopters, Liam, Elizabeth, Eric and Russell. The framework provides an objective measure from which to make evaluative statements about how the teachers have used geospatial technologies to enhance students' thinking through their geography teaching.

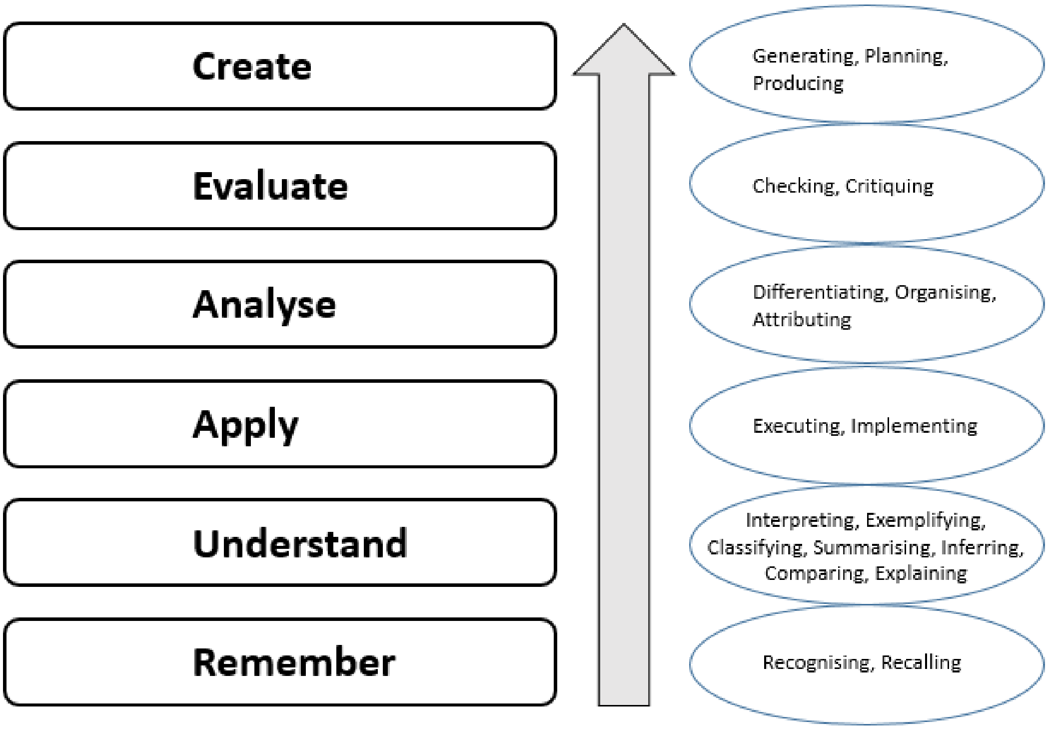


Figure 8.1. Evaluative framework derived from Anderson et al.'s (2001) revision of Bloom's *Taxonomy of Educational Objectives, Volume 1: Cognitive Domain*.

8.3 Geography Knowledge

The analysis of the early adopters' teaching artefacts also identified the types of geography knowledge that students could develop through completing the GST-enhanced activities. Recent research, published since the teaching artefacts were collected and analysed in this study, has illustrated the value in combining Anderson et al.'s (2010) revision of the Taxonomy with the "dimensions" of geography knowledge taught by geography teachers (factual knowledge, conceptual knowledge, and procedural knowledge) (Bijsterbosch et al., 2017, p. 22). This newly developed framework could yield valuable insights into how Bloom's cognitive processes and "core [geography] knowledge" (Bijsterbosch et al, 2017, p. 18) can be brought together to deepen students' geography learning. The geography knowledge dimensions described by authors can be summarised as follows:

Factual knowledge. Factual knowledge is the "specific details and elements" (Bijsterbosch et al., 2017, p. 22) related to the topic studied (e.g. knowledge of Australian towns and cities).

Conceptual knowledge. Conceptual knowledge relates to knowledge of "geography classifications, categories and principles" (p. 22) (concepts) and the relationships between concepts. *Australian Curriculum: Geography* includes many geography concepts, including place, space, sustainability, change, interconnections, scale and environment.

*Procedural knowledge***.** Procedural knowledge includes knowledge of geography methods and geography sills. *Australian Curriculum: Geography* outlines the key methods and skills to be taught to Australian students within its inquiry framework: observing, questioning and planning; collecting, recording, evaluating and representing; interpreting, analysing, and concluding; communicating; reflecting and responding.

While this study was conducted prior to Bijsterbosch et al.'s (2017) publication of their developing framework, the value of their contribution for evaluating geography teaching is acknowledged in this study by the inclusion of four tables (see Tables 8.2, 8.3, 8.4, and 8.5) that illustrate the geography knowledge taught to students through the early adopters' teaching artefacts. Further research about the use of GST in geography teaching could use Bijsterbosch et al.'s (2017) framework to develop additional insights into teachers' practices.

8.4 Survey Results

Evidence of how geography teachers make use of geospatial technologies in their geography teaching can be drawn from the *GST4GEOG* survey. Fifty-one participating teachers provided a written response to an open-ended question asking them to explain an activity which uses geospatial technologies for teaching the concepts and skills of secondary geography. Using the analysis strategy described by Driscoll, Appiah-Yeboah, Salib and Rupert (2007), teachers' open-ended responses were collated, examined for patterns and themes and transformed into a series of binary codes (1 = themes present in response, 0 = absent). This analytical strategy has been adopted throughout the study to identify patterns in teachers' responses to open-ended survey questions (see Chapter Four: Research Methodology for further justification of this analysis strategy). This strategy resulted in the identification of 23 geographical concepts or skills for which the teachers reported using geospatial technologies to teach. The activities that teachers described were found to be related to: developing students' mapping skills; teaching physical features and processes; teaching land cover change; undertaking fieldwork; and examining liveability conditions. The frequency in which the teachers referred to teaching these concepts and skills using GST is reported in Table 8.1.

Activities that use geospatial technologies to teach mapping skills were the most commonly reported use of GST. Responses to the open-ended question included statements about teaching “country locations”, “the distance between Australia and Gallipoli” and “to show students maps of their local area” (anonymous survey participants). These responses indicate that a proportion of the teachers adopting GST in the classroom do so as an alternative way of teaching mapping activities traditionally taught using atlases and world globes. Similarly, several early adopters reported using GST to “show” students physical geography processes, such as “longshore drift up the east coast”, “the topographical influences on biomes” and the “before and after effects of bushfires” (anonymous survey participants). These responses indicate the use of GST as a demonstration or explanation tool and do not make any reference to students’ own use of GST for undertaking geography/geographical analysis. Evidence from the survey suggests that many early adopters may be using geospatial technologies to model an activity or to share a geographical concept with students.

Table 8.1

Geography Concepts and Skills Taught Using GST: Frequency of Responses

Geography concepts/skills	**Freq. of responses**
Mapping skills	26
• Plotting locations; interpreting local area maps; finding directions; measuring distance; using GIS layers; examining different scales	
Physical features or processes	14
• Plate tectonics; continental drift; longshore drift; landforms/landmarks; weather; biomes; natural disasters; climate	
Land cover change	7
• Urbanisation	
Fieldwork	4
• Data collection; geotagging fieldwork photographs	
Liveability	3
• Assessing resource needs; comparing living conditions between populations	

N = 51 teachers. Note: In some instances, teachers referred to more than one teaching activity using GST, while others did not provide any description of an activity.

8.5 Teaching Artefacts

Given that the use of GST for geography education is a relatively new curriculum requirement, the fact that many early adopters report utilising GST in these relatively limited ways is perhaps unsurprising. As previous GST education research suggests, the provision of ready-made teaching materials and the availability of additional professional learning opportunities could work to support teachers to use GST in more creative and innovative ways (Tan & Chen, 2015). The remainder of this chapter consists of an evaluation of how some early adopters are using GST in their geography teaching and may go some way towards demonstrating how geospatial technologies can be integrated into learning activities in ways that enhance geography teaching and require students to engage in more sophisticated and complex types of learning. Four of the early adopters in this study, Liam, Elizabeth, Eric and Russell, provided detailed 'teaching artefacts' to the researcher. These artefacts included stand-alone learning activities, assessment tasks and unit plans. In analysing these artefacts with reference to the framework adapted from Anderson et al.'s (2001) revision of Bloom's Taxonomy, exemplars of geography teaching by early adopters utilising GST are presented.

8.5.1 Liam's Teaching Artefact

Liam's teaching artefact is an activity he uses with his Year 9 students. In the activity, Liam's students watch a video on YouTube of Lucky Starr's song *I've Been Everywhere, Man* and plot the Australian towns and cities mentioned in the song in Google MyMaps. To complete the task, students work in small groups, watching the YouTube video, listing the locations mentioned in Google Sheets, and searching for, identifying and using a placemark to plot the locations in Google MyMaps. Students access the task requirements using the Google Classroom online learning platform. A screenshot of Liam's teaching artefact demonstrates how Liam uses the Google Classroom platform to provide students with links to the YouTube video and instructional text and videos for using Google MyMaps (Figure 8.2).

I've been everywhere man

Time: 2 Lessons

Submission: Share your map with Mr [redacted] and Mr [redacted]

Find the lyrics to "I've been everywhere man" by Lucky Starr. Here is a youtube link
https://youtu.be/SMCo1_n8-9k
(Pro tip: Make sure you are watching the Australian version, not the American version.)

1. Identify all the place names mentioned in the song
2. In Google MyMaps, plot each location. You'll need to make a list on Google Sheets.

For instructions on using Google MyMaps, click this link:
https://support.google.com/mymaps/answer/3024396?hl=en

Figure 8.2. Liam's teaching artefact demonstrating his use of Google MyMaps.

How Liam teaches this activity is informed by his pedagogical knowledge, his knowledge of how his students learn and his beliefs about the value of social constructivist learning theories. In describing this lesson, Liam emphasises his student-centred approach to teaching:

> (p. 17, 454-468): We come together in the open learning area and we use Google Classroom. We basically give [students] an assignment or project for that lesson and the kids know how to come in and just get started. They open up Google Classroom and see what the task is and just get going. So that's a group work kind of activity, so using those sort of constructivist theories of knowledge and it's also student directed. The teachers kind of

> stand back. We don't do much talking. Pretty much no talking in those kinds of settings at all.

Liam's lesson makes use of technology both in facilitating the learning (through Google Classroom for sharing the activity instructions with students) and in using geospatial technologies for the mapping task. Liam's reflection that he and his teaching colleague "stand back" and "don't do much talking" during the activity exemplifies Liam's beliefs that when technology is used in the classroom, teachers should allow students to develop their understanding in collaboration with peers.

Additionally, Liam's approach to teaching this activity speaks to the positive learning culture he has developed in his classroom. Liam's matter-of-fact approach to describing how he teaches this activity belies the extensive pedagogical work he has undertaken to build students' understanding and capacity to complete this task without explicit teacher direction. When entering the classroom, students have clear understandings of Liam's expectations for their learning and have developed the required skills and knowledge to work collaboratively with their peers as a result of Liam's on-going commitment to embedding social constructivist learning theories in his teaching.

Although Liam employs limited explicit instruction during the activity, his description of his teaching in the lead up to the activity underscores his high level pedagogical practices in scaffolding students' learning with geospatial technologies. Liam said, "we need to do, in the lead up, we need to do an almost discrete education, a little lesson on MyMaps, how to save MyMaps, just to explain to students what layers are in GIS and some of the terminology" (p. 3, 64-49). Liam's ability to provide for students' learning of the technical skills for operating Google MyMaps and his capacity to seamlessly integrate this instruction into his geography pedagogy demonstrates Liam’s strong technological, pedagogical and content knowledge (TPACK). In designing this activity, Liam has a clear understanding of what students need to know, be able to do, and be able to understand in order to be successful in the activity. Explicit technology instruction, coupled with clear expectations for how, and with what purposes, students work together, and appropriate geography content are expertly woven together to make for an engaging, relevant and effective lesson activity.

Liam’s stated intention in this activity is for students to work in groups to construct their understanding of the spatial distribution of towns and cities. “In this scenario”, Liam stated, “students were able to work on their devices with limited explicit teaching” (personal email communication). As an effective teacher, however, Liam knows that his students learn at different rates and in different ways. Liam provides additional scaffolding for his students by employing instructional texts and videos to support students during the activity. Liam refers his students to the Google MyMaps tutorial videos created by Google, allowing those students who need to be additionally guided in their use of the technologies to take responsibility for their own learning and seek out the specific help they need to be able to complete the task. Liam’s use of these tutorial videos is a strong indicator of his highly-developed technological, pedagogical and content knowledge. Liam employs technology both as a means for students to complete the task and as an instructional aid. Students’ technology specific questions can be appropriately addressed by the tutorial videos, thus allowing Liam to focus on how best to facilitate higher order geographical thinking amongst his students.

Liam’s activity is strongly student-centred. In explaining his planning decisions, Liam stated, “I need to know myself and assess where [the students] are at”

(p. 11, 257-258) before making use of geospatial technologies in teaching. In designing this activity, Liam draws on his pedagogical knowledge and his knowledge of his students' learning to make an informed decision about the students' capacity to successfully use the technology. Liam's decision-making is informed by his skilful use of "a lot of small assessment steps" (p. 11, 258) to formulate his judgement about student readiness to complete the activity. As such, Liam's utilisation of geospatial technologies in his geography teaching is borne out of his deliberate pedagogical response to students' skill development and learning in geography.

Liam's activity requires students to understand, analyse and apply geographical concepts and skills, communicating their learning through a creative and subject-specific medium. When analysing Liam's activity in relation to the framework adapted from Anderson et al.'s (2001) revision of Bloom's Taxonomy, there is clear association between Liam's activity and the verbs that describe students' thinking skills at the middle and upper levels of the Taxonomy (Figure 8.3). In Figure 8.3, those Bloom's verbs evident in Liam's activity are coloured yellow, while the red text denotes alternative verbs that could be used to describe Liam's activity at each level of the cognitive domain.

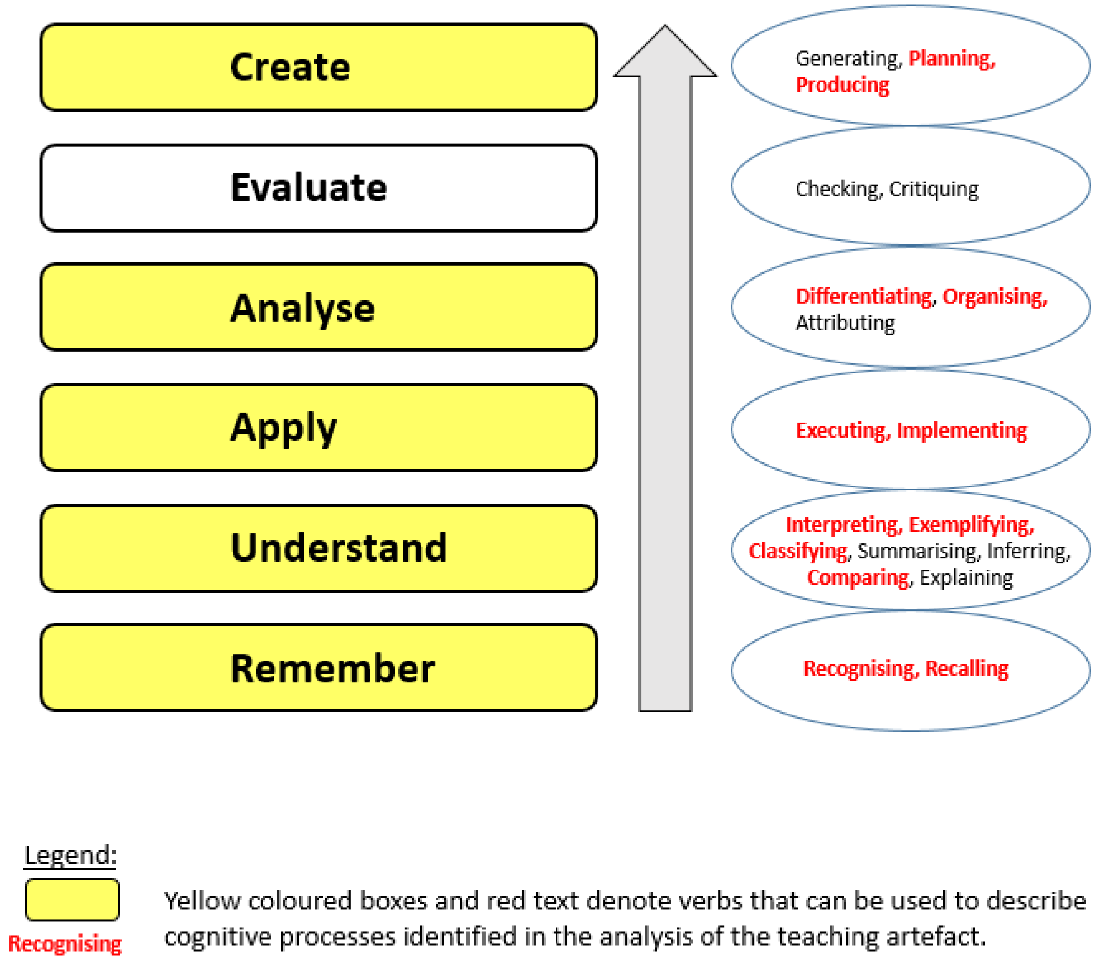


Figure 8.3. Evaluation of Liam's artefact, adapted from Anderson et al. (2001). Yellow coloured boxes and red bolded-text identifies those verbs that can be used to describe Liam's artefact.

Students engage in an initial process of listening to the YouTube video and identifying Australian towns and cities that are mentioned in the song. This element of the activity aligns with Bloom's levels of 'remember' and 'understand' and corresponds with Anderson et al.'s (2001) categorisation of lower order thinking skills of 'recognising and recalling' and 'interpreting, exemplifying, classifying and comparing.' By building in these lower-order thinking skills into the first component his activity, Liam provides all students with success opportunities and cements their capacity to engage in the more challenging parts of the activity. In finding and listing the towns and cities, students have the knowledge needed to engage in the levels of ‘apply’ and ‘analyse’, mid-levels of the Taxonomy. Accordingly, students engage with Anderson et al.’s (2001) verbs of ‘executing and implementing’ and ‘differentiating and observing’ in structuring their Google Sheets list of Australian towns and cities and in organising how they will respond to the second part of the activity: the creation of a map of the towns and cities using Google MyMaps.

This final element of Liam’s activity represents the highest level of the Taxonomy, requiring students to use Google MyMaps to create a map of the towns and cities mentioned in the YouTube video. In this part of the activity, students demonstrate skills and knowledge that align with the top of Bloom’s hierarchy (‘create’), corresponding with verbs ‘planning and producing.’ This component of Liam’s activity best demonstrates his knowledge and understanding of how geospatial technologies can enhance his geography teaching. By using geospatial technology in this activity (rather than paper maps or atlases), students must respond to the activity with greater creativity and with a more complex understanding of the geography concept of spatial distribution. Liam’s reflections on the success of the activity are further evidence of how, in his design of the lesson, he was able to combine geography content, pedagogy and technology to strongly enhance students’ learning:

> Liam: (p. 6, 132-139): My objective was for them to learn GIS software and the actual learning was about the range of locations in Australia and sort of developing their knowledge of those sorts of things. It kind of surprised me and next year I’m going to put in more time for this type of unit to spread over more lessons.

Liam’s reflections on the impact of this activity on students’ geography learning is evidence of how he can use geospatial technologies to promote high-level geographical understanding, rather than using the technology as a mere tool for low-level engagement.

Liam's teaching artefact provides opportunities for his students to develop some factual, conceptual and procedural geography knowledge. Students learn about the locations of towns and cities in Australia and the concepts of place and location. They develop the procedural geography knowledge required to represent geographical data using Google Sheets and Google MyMaps technology. The geography knowledge represented in Liam's teaching artefact aligns with his rationale for designing the task; the introductory nature of this task teaches few geography concepts and skills but allows students to consolidate and practice their use of the Google technologies for representing their geography learning.

Table 8.2.

Geography Knowledge in Liam's Teaching Artefact

Geography Knowledge
Factual Knowledge
• Knowledge of locations (towns and cities) in Australia
Conceptual Knowledge
• Knowledge of geography concepts: place, location
Procedural Knowledge
• Knowledge of representing geographical data: Google Sheets and Google MyMaps

Additionally, Liam's teaching artefact provides clear insight into his capacity to combine geospatial technology with geography content and pedagogy; that is, his technological, pedagogical and content knowledge (TPACK). In Chapter 6, Liam's self-reported TPACK was reported. For ease of readability, it is repeated here.

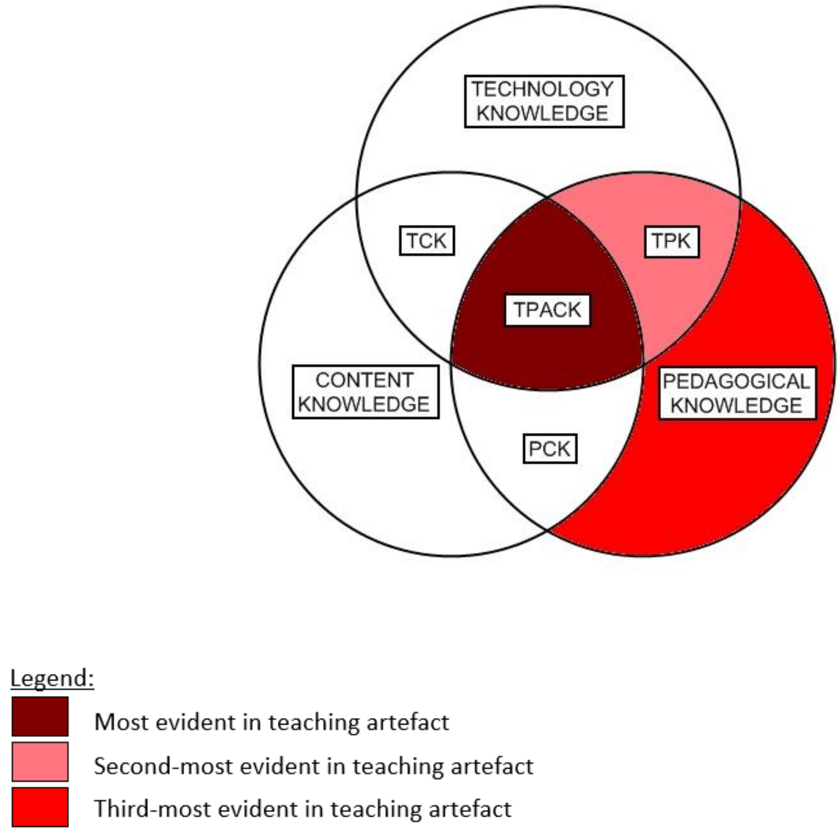
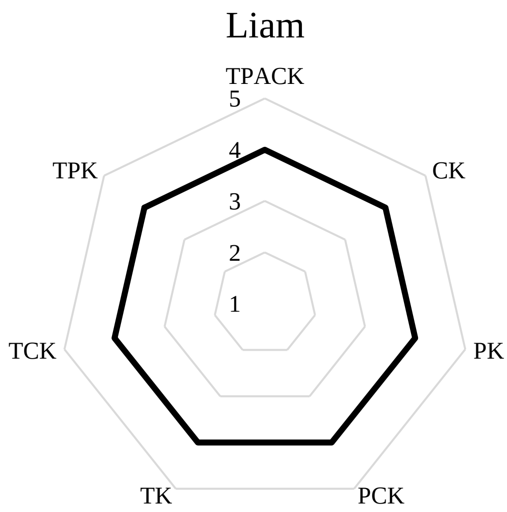


Figure 8.4. Liam's enacted TPACK as demonstrated in his teaching artefact

Liam's enacted TPACK closely mirrors his self-reported technological, pedagogical and content knowledge as recorded in his survey responses. Liam's results indicate a belief that he is equally knowledgeable in all of the TPACK domains (Figure 8.5). Analysis of his learning activity provides additional evidence of Liam's highly developed knowledge, particularly in the domains of PK, TPK and TPACK.



CK	PK	PCK	TK	TCK	TPK	TPACK
4.00	4.00	4.00	4.00	4.00	4.00	4.00

Figure 8.5. Liam's self-reported TPACK derived from survey results

As evidenced by Liam's own reflections on his practice, Liam's approach to planning and teaching *I've Been Everywhere, Man* has been strongly influenced by his preference for pedagogies underpinned by constructivist learning theories. Figure 8.4 is a visual representation of Liam's enactment of his TPACK in planning and teaching the learning activity. Liam's TPACK, as demonstrated through his use of the Google MyMaps platform, is represented in the centre of the figure (dark red). Liam's commitment to the implementation of constructivist learning theories in his activity is represented in the figure in bright red and reflects Liam's pedagogical knowledge (PK). Liam's appreciation of the value of Google MyMaps as a tool for supporting his constructivist pedagogies is represented in light red in the figure and reflects Liam's technological pedagogical knowledge (TPK). While the *I've Been Everywhere, Man* learning activity combines technology, geography content and pedagogy, Liam's stated intentions in utilising Google MyMaps was to support students' collaborative development of their geography knowledge and skills, demonstrating Liam's pedagogical knowledge (PK, TPK and TPACK) and its influence on his teaching practice.

8.5.2 Elizabeth's Teaching Artefact

Elizabeth's teaching artefact is a summative assessment task that she has used with her Year 10 students. The assessment task follows on from a fieldwork excursion in which the class visited a range of locations along the Adelaide coastline. The purpose of the excursion was for students to learn about the physical processes and environmental challenges that affect Adelaide's coastline and the management strategies in place to mitigate environmental degradation. While on the excursion, students collected geographical data about the coastline in the form of observational notes, photographs and field sketches. Elizabeth's summative assessment tasks represent an opportunity for the students to reflect on and draw conclusions about environmental impacts on the coastline and how coastal management practices can be sustainably improved to benefit recreation, tourism, local businesses and residents. In the assessment task, students are required to represent their learning using the Google MyMaps platform, creating a story map that demonstrates their knowledge of the geographical issues that relate to each location.

To complete the task, students work in groups, creating a new MyMaps template and importing locations of the fieldwork sites from Google Sheets into MyMaps. Students further import photos and videos from their fieldwork excursion that support their understanding of the physical processes and environmental challenges that impact on Adelaide's coast. Students are then required to annotate the map, providing a narrative about the physical processes and environmental challenges that they observed before drawing conclusions and making judgements about how the area can be sustainably managed. Elizabeth's task emphasises the transformation of students' geographical data (e.g. photographs and videos) through online applications, such as Skitch (an application for annotating photographs and screenshots), to best represent their understanding of the geographical processes at work along the Adelaide coast. Students are encouraged to also include additional layers of geographical data in their maps as a form of extension (Figure 8.6).

Year 10 Geography 2015
Unit 3: Coastal Management
SUMMATIVE ASSESSMENT TASK

Adelaide Coastline Story Map

Background

Adelaide's metropolitan coastline is a highly developed and heavily managed stretch of coastline in South Australia. As geographers we are concerned about:

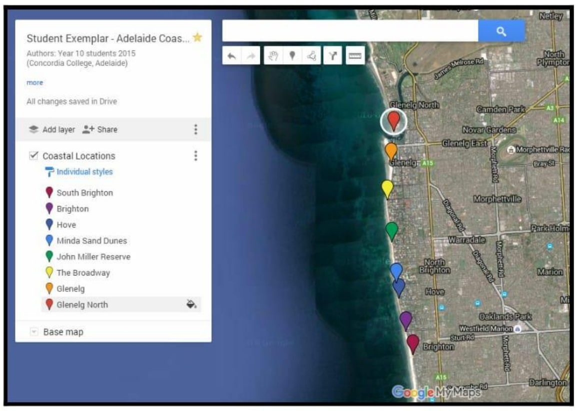
- The ***physical nature*** of the coastline, and the ***physical processes*** operating,
- The ***environmental changes*** which have and will continue to occur to this coastal environment
- Coastal ***management strategies*** being applied in the region,
- How the coastline can be improved ***sustainably*** to benefit EITHER: Recreational use, Tourism, Local businesses, or Local residents

Your Task

Create a Story Map using Google My Maps to:

- show each location visited and what is happening at each location
- explain the points outlined above

Your Story Map can be created as a group and worked on together.



How to create a Story Map

1. Create a **new map** in My Maps.
2. **Share** that map with your other group members and your teacher. Give them editing rights.
3. Create your **first layer**:
   a. **Import** your Google Sheet of the locations visited.
      i. ***style*** this information accordingly
   b. **Add photos and videos** to your maps
      i. make sure your photos have been "Skitched" and that videos have been edited appropriately.
      ii. images of graphs can also be added to your results
4. Add a **title** and **description** to your map. In your description include the following:
   a. the focus area of the study (introduction)
   b. a summary of:
      i. physical processes as work
      ii. environmental changes to the coastal environment
      iii. human impacts and management strategies
   c. Recommendations:
      i. what needs to occur to make this area more sustainable for (tourists, recreational users, business owners, local residents)
5. Once you've got these essential elements on your map, you may wish to add more layers of relevant information.

Page 1

Figure 8.6. Elizabeth's teaching artefact demonstrating her use of Google MyMaps.

The following de-identified student work sample demonstrates the success of Elizabeth’s assessment task (Figure 8.7). In the work sample, these students have been able to present their raw geographical data and their analysis of that data using the Google MyMaps platform. In this instance, the students have used the technology to communicate their knowledge of the physical processes of erosion and their assessment of the effectiveness of the coastal management strategy (rock walls) designed to mitigate the effects of erosion. By ‘skitching’ their photograph, the students represent and communicate why and how they have drawn their conclusions. In plotting the locations of each of the fieldwork sites in their map, students also deepen their knowledge of the geographical concepts of place and spatial distribution.

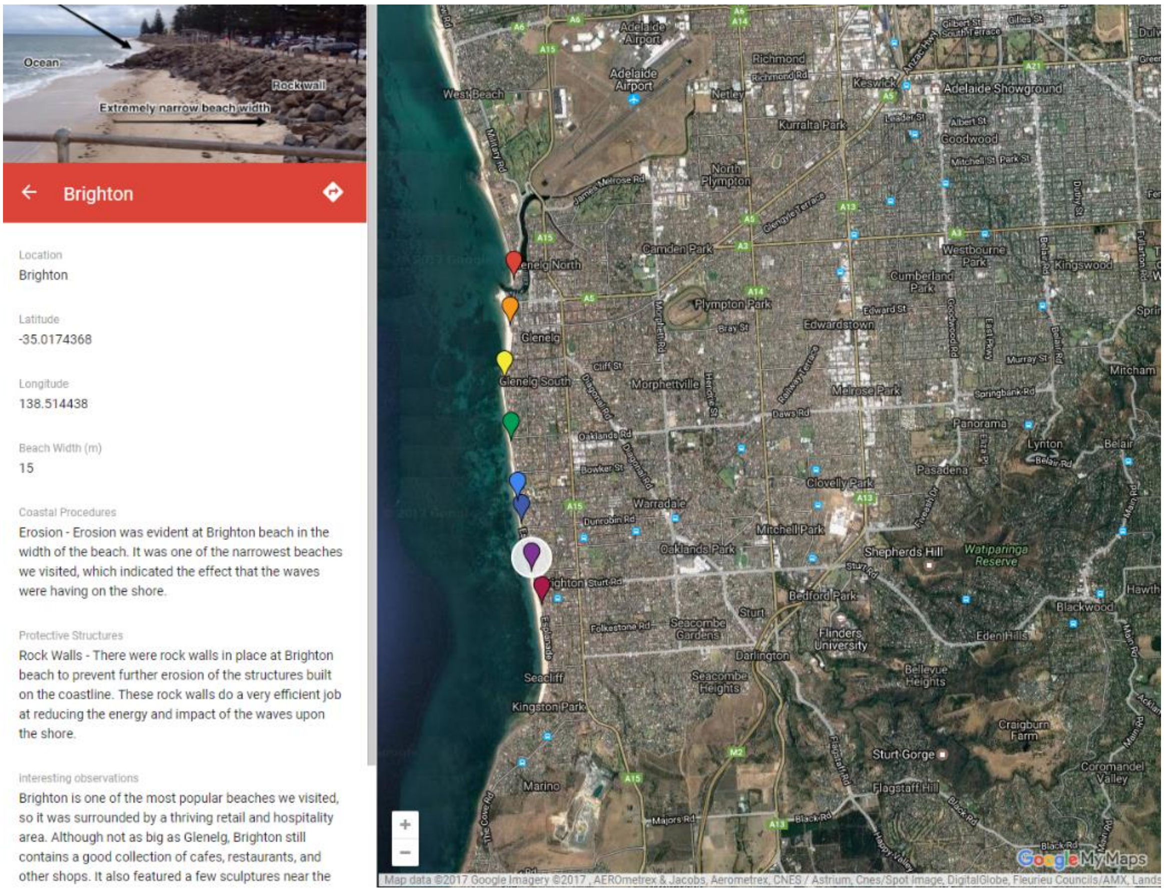


Figure 8.7. Student work sample from Elizabeth’s class.

In designing this summative assessment task, Elizabeth was highly cognisant that the use of geospatial technologies requires students to think critically about what they present and why. Elizabeth's explanation speaks strongly to her highly developed knowledge of how students learn and which pedagogies can drive them to engage in higher-order geographical thinking.

> Elizabeth: (p. 20, 486-492): I also think that using that technology, using the Google Map, kind of helps students to become a bit more concise. You've only got a limited amount of time or space. You're trying to attract the reader. You know, I think it just requires of them a higher level of thinking – what am I really trying to say here? What is the essence of it? Because kids can fill a page with lots of nonsense but not get to the essence of it.

Elizabeth's comment emphasises her knowledge of both the pedagogical opportunities presented by geospatial technologies and also her understanding of how students typically engage with and represent their knowledge of geography content. Elizabeth believes that written reports encourage students to write pages of "nonsense" which fail to adequately demonstrate their geography learning. For Elizabeth, the introduction of geospatial technologies to an activity adds a level of complexity, encouraging students to more critically and concisely convey their geographical understanding. Elizabeth's use of Google MyMaps as a tool for enhancing student learning outcomes is an expression of her deep technological, pedagogical and content knowledge; that is, Elizabeth knows that Google MyMaps represents the best way to students for share their learning of physical processes and environmental challenges affecting Adelaide's coastline.

Elizabeth's design of the assessment task is also informed by her reflections on her past geography teaching and her willingness to experiment with different pedagogical strategies. In a previous iteration of the task, Elizabeth experimented with students using video cameras to record their learning:

> Elizabeth (p. 19-20, 466-476): I still need to work on it. I tried it for the first time last year after getting bored with kids writing written reports. I found them so boring because they become so much the same kind of thing. The other thing we tried with that was a video and it was OK but the kids were not getting it. They were just making it a fun, joke video. They were missing the essential points to be made about what's happening here? And what's happening there? So I went for the spatial technology – apart from the fact that I wanted them to use the technology – I thought we can use maps to tell a story, we can use maps to show us what's going on there.

Elizabeth's comments demonstrate her reflexivity as a teacher; that is, her capacity to identify why the video activity was ineffectual and to make changes to her practice to respond to how students perceived and performed this activity. This experience has strongly informed Elizabeth's technological, pedagogical and content knowledge. Elizabeth knows that in her teaching context, video technology is not the best way to represent students' learning of geography concepts and skills. Instead, Elizabeth believes her purposeful application of geospatial technologies to this activity more effectively allows for the critical synthesis and concise articulation of geography knowledge that she looks for in her students' assessment tasks.

Indeed, Elizabeth's assessment task requires students to demonstrate a depth of factual, conceptual and procedural geography knowledge (Table 8.3). Specifically, Elizabeth's students are provided with opportunities to learn key locations along the Adelaide coast and the environmental management strategies that are utilised to mitigate the environmental challenges experienced at each location. Students engage with and demonstrate conceptual knowledge of place, change, sustainability and human-environment interaction and the illustrate understanding of the relationship between these concepts. Procedural knowledge is demonstrated in three ways – by demonstrating knowledge of fieldwork methods; knowledge of representing geographical data in Google Sheets and Google MyMaps; and knowledge of communicating geographical ideas through writing summaries and recommendations. Elizabeth's assessment task requires students to draw on all three dimensions of geography knowledge to successfully complete the task.

Table 8.3

Geography Knowledge in Elizabeth's Teaching Artefact

Geography Knowledge
Factual Knowledge
• Knowledge of locations along Adelaide coast
• Knowledge of environmental management strategies
Conceptual Knowledge
• Knowledge of geography concepts: place, environmental change, sustainability, human-environment interconnection
Procedural Knowledge
• Knowledge of fieldwork methods: photography and video
• Knowledge of representing geographical data: Google Sheets and Google MyMaps
• Knowledge of communicating geographical ideas: summaries
• Knowledge of reflecting and responding: making recommendations

Elizabeth's deliberate use of geospatial technologies in the assessment task also provides opportunities for students to engage in higher-order thinking that meets the higher levels of learning described in Bloom's Taxonomy. In requiring students to find, analyse, and evaluate geographical data and to create a new product (a map using the Google MyMaps platform), Elizabeth has built into her assessment task opportunities for students to demonstrate their capacities in each of the domains described by Bloom and revised by Anderson et al. (20001): ‘remember’, ‘understand’, ‘apply’, ‘analyse’, ‘evaluate’ and ‘create’ (Figure 8.8). Likewise, Elizabeth’s assessment task provides opportunities for students to demonstrate a range of higher-order thinking skills, including ‘critiquing’, ‘planning’ and ‘producing,’ Elizabeth’s capacity to develop an assessment task that brings together geospatial technologies, geography content and pedagogies and that fosters these higher-order thinking skills is testament to Elizabeth’s highly developed technological, pedagogical and content knowledge.

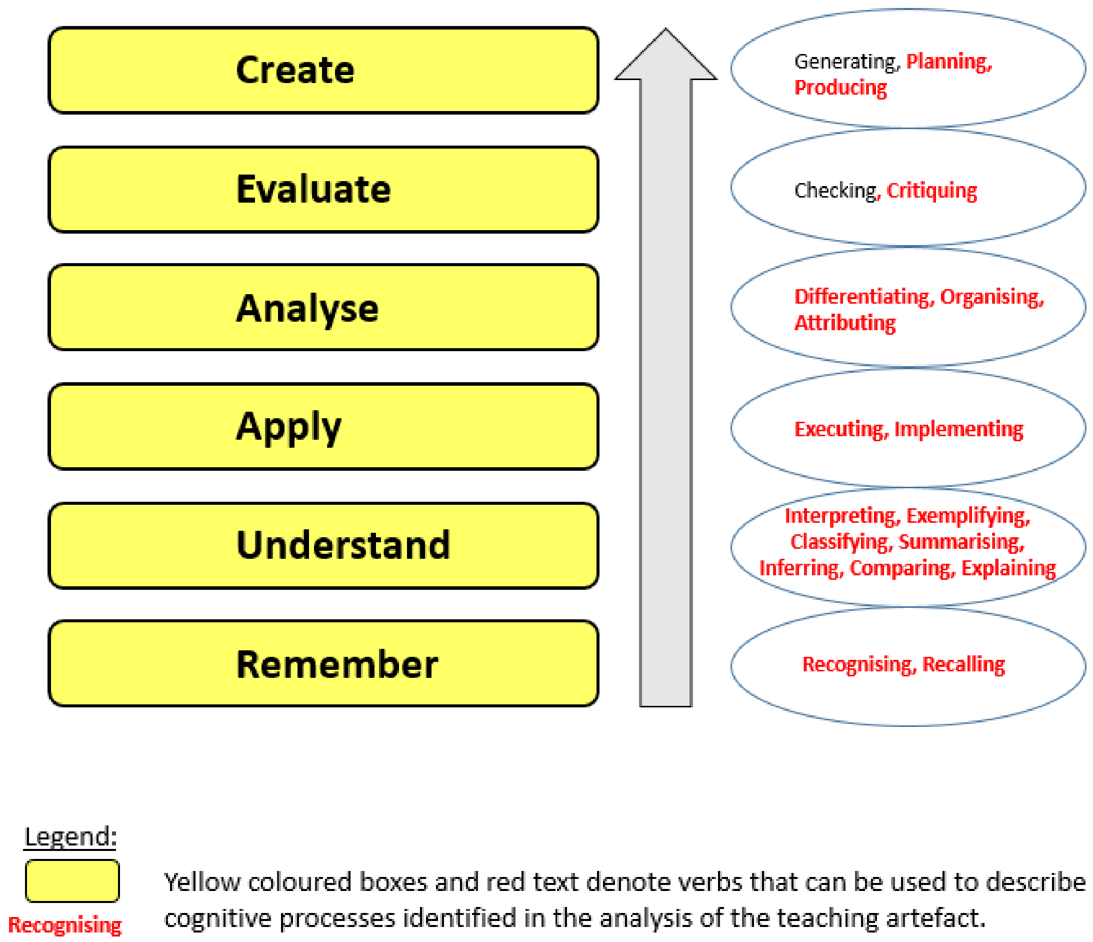


Figure 8.8. Evaluation of Elizabeth’s teaching artefacts.

Analysis of Elizabeth's summative assessment task and her reflections on her motivations and decision-making processes in designing and teaching the task provides evidence to support Elizabeth's own self-reported assessment of her strong technological, pedagogical and content knowledge (Figures 8.9 and 8.10).

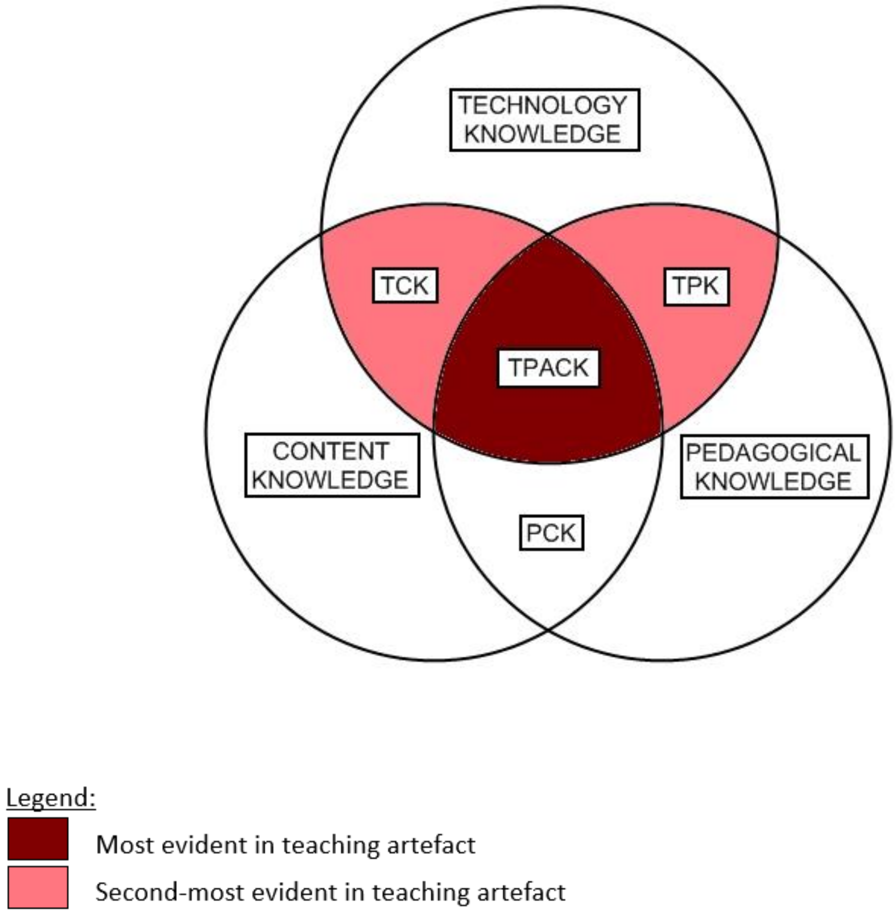
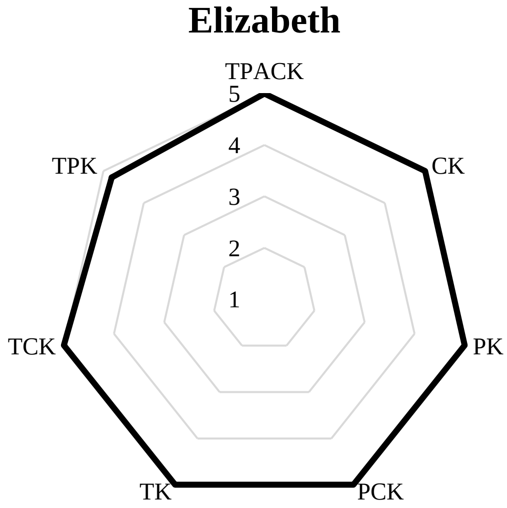


Figure 8.9. Elizabeth's enacted TPACK based on analysis of her teaching artefact.



CK	PK	PCK	TK	TCK	TPK	TPACK
5.00	5.00	5.00	5.00	5.00	4.80	5.00

Figure 8.10. Elizabeth's self-reported TPACK.

While reflecting on her task, Elizabeth spoke to a previous iteration of the task (students making a video) and explained why she instead chose to utilise geospatial technologies in her most recent teaching. For Elizabeth, geospatial technologies represent the best way for students to effectively and concisely communicate their geographical knowledge. In designing and teaching the assessment task, Elizabeth clearly demonstrates her strong technological content knowledge (TCK); that is, Elizabeth knows that the Google MyMaps platform is a more effective mechanism for representing geography content than the video. Similarly, Elizabeth's choice to use geospatial technologies instead of video technology is further demonstrative of her knowledge of her students and how they learn. Elizabeth's reflections on student behaviour and/or dis-engagement with the video task represents strong knowledge of the technology-related pedagogical strategies that work best for her geography learners (TPK). The particular emphasis on Elizabeth's enacted TPACK, TCK and TPK are represented in figure 8.9. As evidenced in Figure 8.10, Elizabeth's enacted knowledge for teaching with geospatial technologies also mirrors her self-reported TPACK as derived from her survey results.

8.5.3 Eric's Teaching Artefact

Eric's teaching artefact is a series of lesson plans which constitute a unit of work for his Year 10 students. *The Great Divide – Spatial Inequality* unit includes ten lessons in which students learn about the geographical concept of spatial inequality and how it relates to the city in which they live (Sydney) (Figure 8.11). The unit contains several geospatial technology-enhanced activities (Figure 8.12). These activities utilise professional-grade GIS software, Esri's ArcMap, and data from the 2011 Australian Census to build students' understanding of the socio-economic demographics of select Sydney suburbs.

In the first activity, students collect data from the 2011 Australian Census database published online by the Australian Bureau of Statistics. In particular, students identify data relating to indicators that can be used to assess the socio-economic characteristics of each of Sydney's suburbs: specifically, average income, tertiary qualifications and unemployment rates. Students record data against the indicators for four of Sydney's suburbs and produce a table which they import into ArcMap GIS.

In the second activity, students use ArcMap to create choropleth maps that demonstrate the spatial distribution of one of the four indicators across the Sydney suburbs. Taking a screenshot of their map, students copy and paste their map into a Microsoft Word document, alongside images of the suburbs sourced from the Internet. The map is shared with Eric when students upload their Word document into Eric's Google Dropbox.

Year 10 2015
The Great Divide – Spatial Inequality (10 lessons)

Field Trip days are: Week 3 – Wednesday 29th July and Friday 31st July 2015

UNDERSTANDING GOALS
Students will come to understand:

- ☐ the meaning of the term *spatial inequality* as it relates to Sydney and the suburb of [redacted]
- ☐ the geographical processes involved in the creation of *spatial inequality*
- ☐ the perspectives of the many stakeholders affected by *spatial inequality*
- ☐ how individuals, groups and governments respond to *spatial inequality* to achieve social justice and equity
- ☐ the 8 step process of the Research Action Plan and its effectiveness as a research tool

Students will develop:
- ☐ a level of appreciation for a just society and the role that active citizenship plays within it

Figure 8.11. Eric's teaching artefact.

In addition to completing activities one and two, Eric includes in his plan explicit communication of the evidence from which he bases his conclusions about his students' understanding of the geographical concept of spatial inequality. To demonstrate their understanding, students additionally have to draw a line of 'best fit' onto their choropleth maps to identify where they think the spatial divide between 'advantage' and 'disadvantage' exists in Sydney. To make this judgement, students need to engage in critical evaluation of the data they have collected and its representation on their choropleth maps. Students then compare their maps to maps printed in their classroom textbooks.

PHASE 3
Spatial Inequality in Sydney
RAP Step 5 Collection of Data

Activity 1 - GIS TABLE OF STATISTICS
Teacher instructs students on the use of ArcMap GIS. Students interrogate ABS 2011 Census data base for statistical data for the suburbs of: [redacted] and the student's own suburb. They complete a table of research findings for each of the indicators: average income, tertiary qualifications and, unemployment rates for each of the four suburbs.

Activity 2 - CHOROPLETH MAP
In pairs, students generate in MS Word a choropleth map of one of the four indicators in Sydney capturing a screenshot from ArcMap. Students source photos of relevant suburbs on the Internet and paste these onto the map. The map is then printed and saved to their teacher's drop box.

Evidence of Understanding
Students draw a line of best fit on their printed choropleth map of Sydney to illustrate spatial inequality according to their indicator of advantage/disadvantage.
Students to compare their maps with text book versions, page 212.

Figure 8.8. Eric's ArcMap GIS activities

Eric's activities incorporate sophisticated technology use: students examine the online Census database for relevant data, map their data in ArcMap, represent their findings in Microsoft Word, and share their work using Google Dropbox. As described in Chapter Six, Eric's school provides for almost-universal technology access and Eric uses that technology to take advantage of the more complex geographical analysis that can be achieved when using professional GIS software.

Eric's capacity to integrate professional GIS and geography curriculum content in a task that is meaningful to his students' lives (i.e. a task that is about their local area, Sydney) is testament to his well-developed TPACK and his long-term efforts to embed geospatial technologies into the school's teaching practices. When describing his design of *The Great Divide – Spatial Inequality* unit, Eric reflected on how his use of geospatial technologies led on from previous activities students completed in Year 9.

> Eric (p. 18, 431-444): We do a bit of a unit I've put together in fourth term where we get them prepared for going on camp, where we can use Google Earth and get them to actually do a thing down the river as if they were in the canoe using Google Earth. So it's making it exciting, real, fun, that sort of thing, to really promote the subject. But there's also having them being aware of the power of interrogating the databases. That's really good. And when they get into the census stuff and see that they can see who speaks Croatian in Glenorie – what the average is – and there's listing stats within that for the kids.

Eric's use in Year 9 of Google Earth, a less complex version of GIS, reflects strong knowledge of student learning and the geographical curriculum progression that is appropriate for Year 9 and 10 students. Eric scaffolds his students' capacity to use geospatial technologies, building their learning of how to represent geographical information using GST from simple web-based technologies to more complex, professional software. By linking the learning of the skills to utilise Google Earth with students' camp preparations, Eric is able to engage Year 9 students in a task that is exciting, relevant and fun. This early preparatory work lays the foundations for students' engagement and interest in the more complex geographical analysis undertaken in Year 10. On commencing the *Great Divide – Spatial Inequality* unit, Eric's students are already familiar with basic geospatial technology operations and know that GST can be used to show their geography learning. Similar to the pedagogical approach taken by Liam, Eric uses instructional videos to support individual students who need explicit guidance on the functions of GIS during lessons.

Eric builds on Liam's practice by making the videos himself, giving clear instructions to students about how to use the specific technologies available to them in the classroom. By adopting this practice, Eric is able to differentiate his teaching, catering for all levels of student need in his classroom:

> Eric (p. 25, 610-619): I've also made a lot of movies…. That's where you've seen me before! No, I've just been showing them with those sort of screen capturing things showing them how to click here and click there so that can help kids. They can put their earbuds in and they can sort of follow step by step for the weaker kids or they're a partnership with someone. So they can do it that way or there are the sort of Google Earth style things, and again I make movies for the kids that might struggle with it.

Eric's use of the videos that he has produced enables him to provide explicit technology instruction to students who need it and frees him up to extend other students' geographical thinking through in-time classroom discussions. In this capacity, Eric demonstrates strong technological, pedagogical and content knowledge in his mastery of employing technology to enhance student learning outcomes.

Through Eric's purposeful use of the Census database and ArcMap GIS, students' geography knowledge (factual, conceptual and procedural) can be developed though Eric's activities (Table 8.4). Students are provided with opportunities to learn factual knowledge of Sydney's suburbs, including knowledge of demographic characteristics (e.g. average income, tertiary qualifications and unemployment rates) for selected suburbs. Students engage with the key geography concepts of place and spatial distribution, specifically the distribution of inequality, advantage and disadvantage in Sydney's suburbs. Procedural knowledge can be developed through conducting research to find geographical data using the ABS Census database, by representing geographical data using ArcMaps GIS and communicating geographical ideas by comparing their choropleth map with those found in their textbooks. In Eric's teaching activities, there is a clear progression of geography learning; students begin by developing factual geography knowledge through their initial research, before engaging with conceptual and procedural knowledge in creating and evaluating their GIS mapping.

Table 8.4

Geography Knowledge in Eric's Teaching Artefact

Geography Knowledge
Factual Knowledge
• Knowledge of Sydney suburbs
• Knowledge of Sydney population/demographic characteristics
Conceptual Knowledge
• Knowledge of geography concepts: place, spatial distribution (inequality, advantage, disadvantage)
Procedural Knowledge
• Knowledge of collecting and recording geographical data: ABS Census database
• Knowledge of representing geographical data: ArcMap GIS, choropleth mapping
• Knowledge of communicating geographical ideas: identifying 'line of best fit', comparing with textbook map

Eric's use of geospatial technologies in *The Great Divide – Spatial Inequality* unit exemplifies high quality geography teaching and learning when compared with the revised version of Bloom's Taxonomy (Anderson et al., 2001) (Figure 8.13). In designing the unit and its activities, Eric engages in a scaffolded process of developing students' learning, moving from lower-order skills of recognising and recalling (synonymous with 'remember' in the revised Taxonomy) to higher-order thinking skills of critically evaluating, designing and constructing GIS choropleth maps from which to make their judgements about Sydney's spatial inequality ('evaluate' and 'create' on the Taxonomy). The use of GIS in this unit allows students to employ those higher-order thinking skills, providing them with opportunities to undertake their own geographical analysis and to represent their analysis on a map that they have created. The transformative value of GIS in this unit is clearly evident when students are asked to compare their GIS maps to versions of the maps in their textbooks. Rather than simply 'showing' students the answer via the textbook, Eric provides the tools and explicit pedagogical support for students to derive their own responses from a critical evaluation of up-to-date Census data. Eric's teaching is demonstrative of high quality practice with technology, expertly integrating geospatial technologies, geography content and strong pedagogical practice.

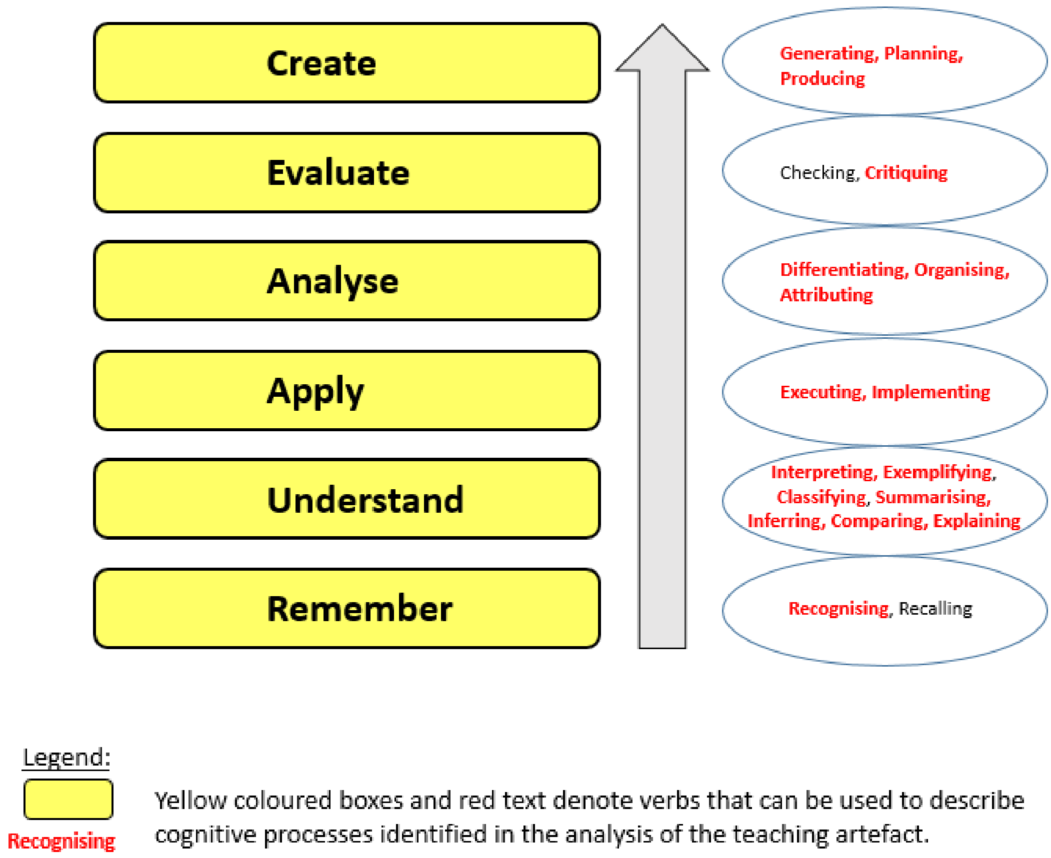


Figure 8.13. Evaluation of Eric's teaching artefacts

Eric's planning and teaching of the geospatial technology enhanced learning activities in *The Great Divide – Spatial Inequality* unit illustrate his strong technological, pedagogical and content knowledge and align with his self-reported perception of his TPACK (Figure 8.14).

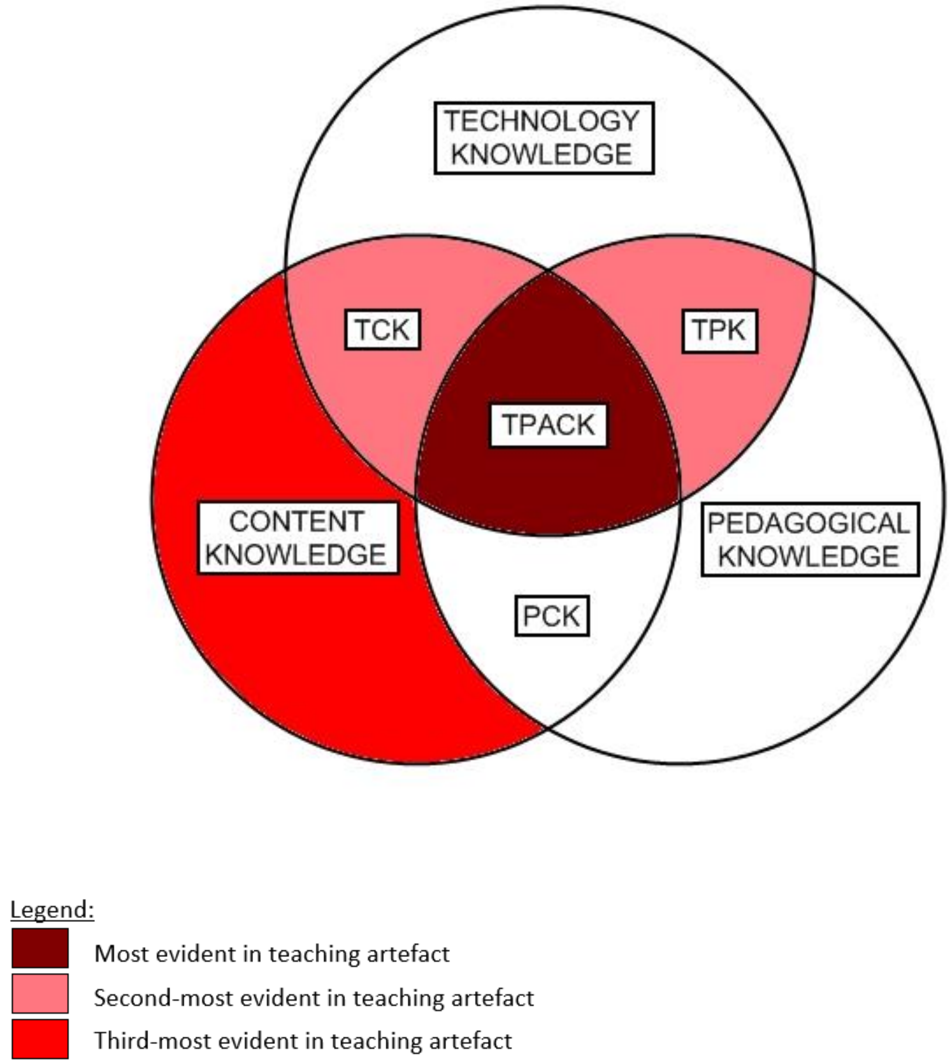
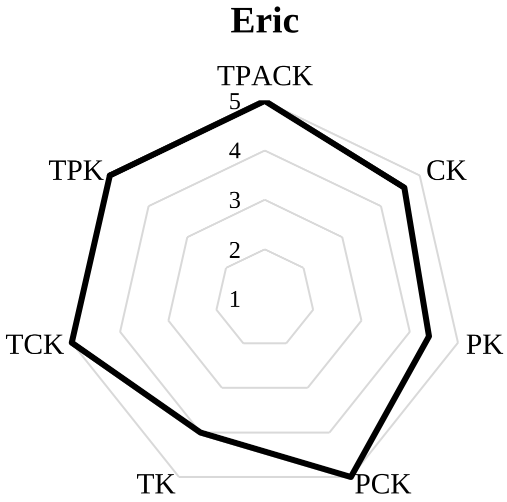


Figure 8.14. Eric's enacted TPACK based on analysis of his teaching artefact.

Eric rated his knowledge most highly in the TPK, TCK and TPACK domains (Figure 8.15). Eric's strong knowledge in these particular domains is confirmed in his enacted GST teaching practice.



CK	PK	PCK	TK	TCK	TPK	TPACK
4.60	4.40	5.00	4.00	5.00	5.00	5.00

Figure 8.15. Eric's self-reported TPACK.

In Eric's activities, geography knowledge is at the forefront: the purpose of students' use of the GIS software is to draw conclusions about the spatial inequalities that exist within and between Sydney's suburbs. Eric's strong geography content knowledge (CK) has enabled the design of learning activities that embolden students to learn about and grapple with the serious geographical challenges that arise from Sydney's spatial inequalities. Eric's incorporation of the use of GIS to create choropleth maps that represent Sydney's spatial inequalities is underpinned by his knowledge of how geography content can best be represented by technology (TCK). Eric's production of tutorial videos to support his students' learning needs during the unit is clear evidence of his technological pedagogical knowledge (TPK), while Eric's capacity to combine GIS, geography content and appropriate pedagogies demonstrates Eric's TPACK.

8.5.4 Russell's Teaching Artefact

Russell's teaching artefact is a series of worksheets which he has used with Year 7 students. The activity, *QR Code Orienteering*, requires students to work in small groups to use their GPS-enabled smartphone/s to identify locations around the school grounds, noting their latitude and longitude on the worksheet (Figure 8.16 and Figure 8.17). Each location is represented by a QR Code (Quick Response Code) and students need to scan each code using an app on their smartphone to be guided to the next location. At each location, students record their approximate latitude and longitude and the time taken to reach each location. Returning to the classroom, students plot the locations that they have visited on a map using Google Earth. After plotting each location using the placemark icon, students respond individually to questions that assess their understanding of latitude and longitude, the accuracy of smartphone GPS technology, and ways in which Google Earth can be used to represent geographical locations.

Russell designed *QR Code Orienteering* as a "first-up starter activity for students new to doing this kind of thing" (personal email communication). In utilising students' GPS-enabled smartphones, Russell takes advantage of a variety of technologies that students bring to the classroom, and designs learning opportunities that encourage students' critical thinking about the accuracy of geographical data that can be collected using everyday technology. Explicit teaching about GPS and how it is embedded within students' phones formed part of Russell's preparatory pedagogical work for this activity. Purposeful whole-class discussion at the end of the activity provided the chance for students to critically reflect on their learning.

Year 7 Geography – QR Code Orienteering
Part 2 - Orienteering

Instructions

1. Get into your groups. Each must have a smartphone loaded with functioning QR code reader and GPS apps.

2. There are eight named checkpoints spread around the school and each group will be assigned a different start location clue via QR code in the classroom (Checkpoint "Homeroom"). Note your start time in the table provided, below, as you leave for your first checkpoint.

3. Head to the destination checkpoint, at which you will find another QR code with the clue to the next checkpoint.

4. At the check point, note the exact time you reach and locate the QR code, then use the GPS app to record accurately the latitude and longitude provided in degrees, minutes and seconds (you might need to round to two decimal places for seconds). Be sure to give the GPS time to settle on co-ordinates.

5. Once you have recorded the lat/long, scan the QR code to receive the location of the next checkpoint and make your way to that location as quickly as possible.

6. Repeat steps 3-6 until the table is complete, then return to the classroom.

Checkpoint table (note that checkpoints are in a random order, except for "Homeroom")

Checkpoint name	Time	**Latitude** (dd° mm' ss.ss" S)	**Longitude** (dd° mm' ss.ss" E)
"Homeroom"	:	37°32'14.79"S	143°49'46.47"E
"Distance"	:		
"Position"	:		
"Orientation"	:		
"Grid"	:		
"Map"	:		
"Scale"	:		

Figure 8.16. Russell's teaching artefact (1)

Year 7 Geography – QR Code Orienteering

Part 3 – Back in class

Aim

Now that you have done your orienteering and (hopefully) collected all the latitude and longitude data using your GPS, you are going to investigate how accurate it is.

Instructions

1. On your computer, run Google Earth. You will need the sheet you had outside with the latitude and longitude co-ordinates written on it.
2. Via Tools > Options > 3D View (tab), make sure Show Lat/Long is set to degrees, minutes, seconds. Click Apply > OK. Remember that Ctrl-L will turn lat/long lines on/off in Google Earth.
3. From the toolbar at the top of the screen, click the Add Placemark button
4. When the New Placemark window opens, accurately type in the latitude and longitude in the appropriate fields, making sure the degrees, minutes and seconds are in the right spots.
5. Name the Placemark in the Name field at the top, describing where the clue was found. Write a clearer description of exactly where the clue was found in the Description window at the bottom. Click OK.
6. Repeat steps 3-5 for all the clues.
7. Then go to File > Save > Save My Places. This will save the placemarks to your computer.

Individual questions

1. Do you think you would be able to find specific places on the earth's surface with your phone GPS? If you were using GPS lat/long only, how do you know you are heading to the correct location?
2. Do the placemarks on Google Earth mark exactly where you found the checkpoints, or is there any difference?
   a. Using the Show Ruler button ( ) in the toolbar, measure the distance between where the placemark is located and the actual location where the clue was found.
   b. How many metres is the difference? Is this error the same for all the placemarks?

Figure 8.17. Russell's teaching artefact (2).

Russell (personal email communication): As part of the exercise introduction I talked about how GPS worked on their phones, and put it in the context of

> spatial technologies. As part of the debrief, we discuss how accuracy did vary (i.e. slight variations in the coordinates recorded by each group) and I compared their results with data from the school's Garmin dedicated GPS recorder. The students' points for each location were mapped together (saved KML files sent to me) and we were able to measure the average within 3-6 meters from the correct point, which is about right for a phone with a good line of sight to a few satellites. We also discussed the referencing inaccuracies of the satellite image within Google Earth, which influenced how their mapped points were visualised.

Russell's description of the elements of the activity and his evaluation of students' success in completing the activity is evidence of Russell's capacity to effectively draw together geospatial technologies, geography content and engaging, purposeful pedagogy within his geography teaching. In providing for a comprehensive overview of how GPS technology works in students' smartphones, Russell makes explicit to students the relationship between geospatial technologies and doing and understanding geography in the real world. By taking advantage of students' own technology, Russell connects geospatial technologies and geography to the students' lived experiences of owning and operating smartphones. The activity highlights to students the capabilities of GPS smartphone technology for doing geography and also illustrates to them how they are already engaging with geospatial data in their own lives. In doing so, Russell makes geography learning meaningful and authentic for his students.

Russell's strong technology knowledge permeates every component of the *QR Code Orienteering* activity. In designing this activity, Russell make use of his knowledge of how GPS works in order to lead his students into drawing conclusions about the accuracy of handheld GPS technology. In making comparisons between their GPS-enabled smartphones and the school's Garmin GPS, students are invited to hypothesise and make judgements about the usefulness of smartphone GPS in real-world contexts. Russell's deep knowledge about the technical operation of the Global Positioning System(s), borne out of his postgraduate study on the topic, enables Russell to design the activity with clear certainty about the different results that students will obtain using their smartphones and the school's GPS device. As a result, Russell is able to use this knowledge to construct a task that requires students to not only collect data using GPS but to also critically evaluate the accuracy of that data.

Russell's teaching activity teaches some factual, conceptual and procedural geography knowledge (Table 8.5). Students can learn about the functions of GPS and how to read and record GPS coordinates. Students engage with the concepts of location, distance and time. Students input their GPS coordinates into Google Earth and communicate their understanding of the difference between their GPS data and the representation of that data in Google Earth (procedural knowledge). In this activity, there is a greater focus on procedural knowledge; the purpose of the task is to teach students how to use and understand their smartphone GPS. Factual and Conceptual knowledge are taught to enable the learning of the procedural knowledge.

Table 8.5

Geography Knowledge in Russell's Teaching Artefact

Geography Knowledge
Factual Knowledge • Knowledge of GPS functions • Knowledge of GPS coordinates
Conceptual Knowledge • Knowledge of geography concepts: location, distance, time
Procedural Knowledge • Knowledge of representing geographical data: Google Earth • Knowledge of communicating geographical ideas: comparing smartphone GPS with Google Earth Placemarks.

Evaluation of Russell's activity against the verbs included in Anderson et al.'s (2001) revised version of the Taxonomy reveals that Russell has been able to design a task that requires students to engage in each level of the cognitive processes hierarchy (Figure 8.18). In utilising their smartphones, students recognise and recall ('remember') their knowledge about the operation of the technology, interpret instructions, collect and explain their data ('understand'). In completing the GPS activity and completing the associated worksheet questions, students 'apply' their knowledge of using smartphone GPS technology and analyse the data, drawing conclusions about what the data tells them about their current geographical location. In engaging in the process of critiquing the data that they collected on their smartphones and comparing it to the school's Garmin device, students engage in the 'evaluate' level of cognitive processes described in the Taxonomy. Finally, in developing a KML file that contains students' own GPS data and comparing that data to the map visualisation in Google Earth, students 'create' a new product for the specific purpose of critically evaluating the accuracy of their data. Consequently, Russell's design and teaching of this activity provides opportunities for students to engage in sophisticated and complex forms of geographical thinking. The use of geospatial technologies in this activity is the catalyst for students' engagement in these higher-order geographical thinking skills.

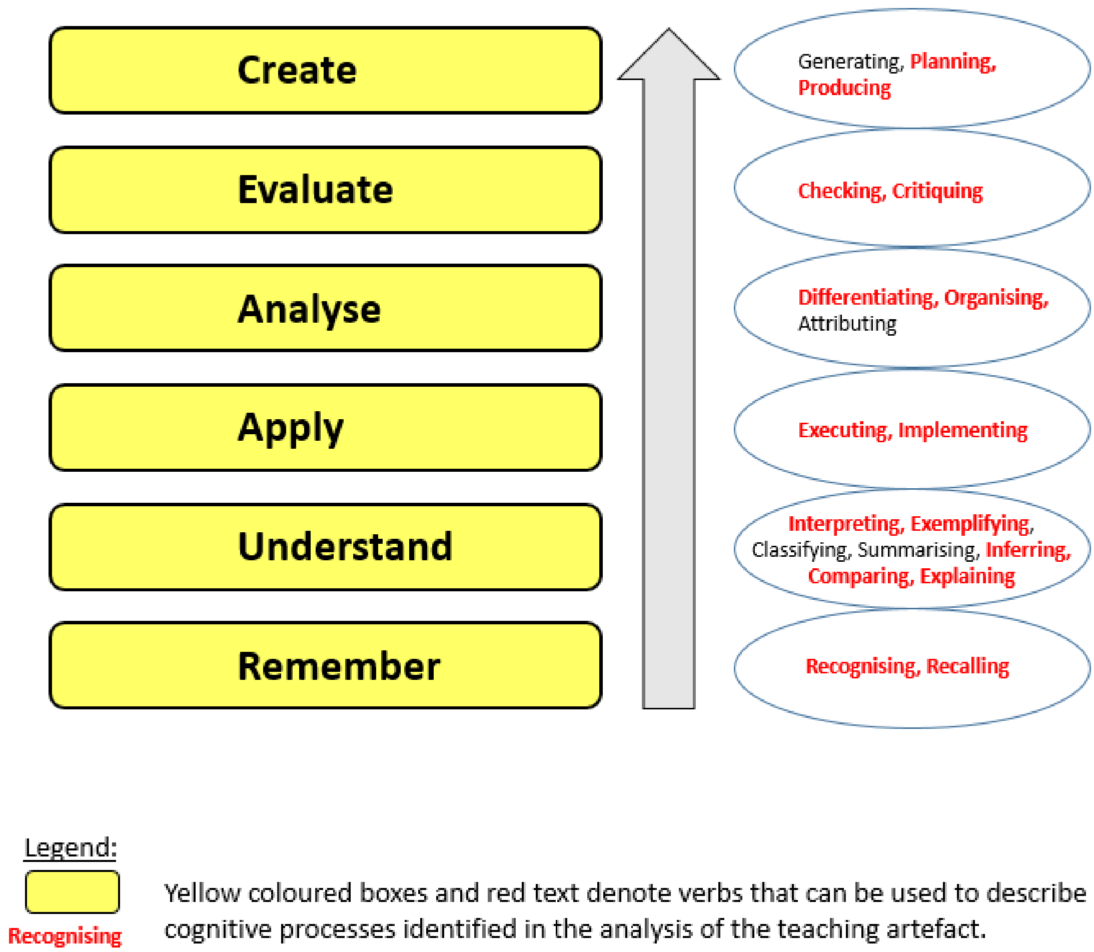


Figure 8.18. Evaluation of Russell's teaching artefact

Russell's *QR Code Orienteering* learning activity is strongly grounded in Russell's high-level technology knowledge (TK). Russell's strong TPACK, TPK and TK as demonstrated by his teaching artefact (Figure 8.19) aligns with his own perceptions of his technological, pedagogical and content knowledge. In his survey responses, Russell indicated being highly knowledgeable in each of the TPACK domains (Figure 8.20). Russell's teaching activity provides further evidence of his high level skills for integrating geospatial technologies, geography content and pedagogies into his planning and teaching.

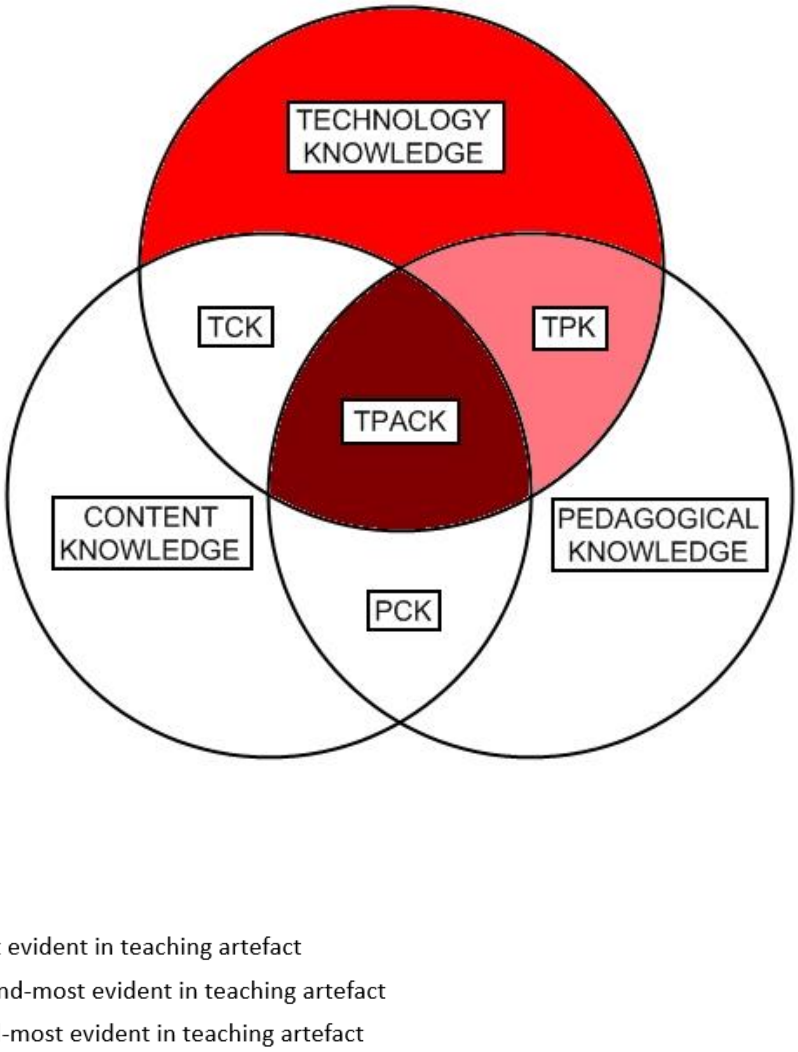
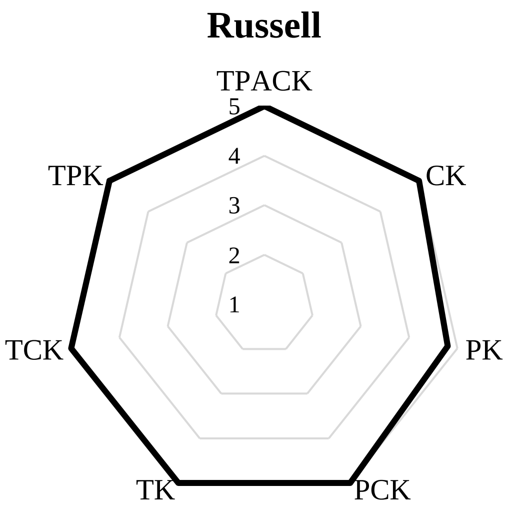


Figure 8.19. Russell's enacted TPACK as evidenced by his teaching artefact.



CK	PK	PCK	TK	TCK	TPK	TPACK
5.00	4.80	5.00	5.00	5.00	5.00	5.00

Figure 8.20. Russell's self-reported TPACK.

While the activity demonstrates Russell's capacity to integrate geospatial technology, geography content and pedagogy (TPACK), the activity's focus on the operation of smartphone GPS applications and their accuracy and/or comparison with a professional grade GPS device is grounded in Russell's clear understanding of how GPS works and his knowledge of the capabilities of smartphone apps compared with professional GPS devices. In providing students with an opportunity to learn about the operation and accuracy of smartphone GPS applications, Russell further exercises his technological pedagogical knowledge (TPK) by utilising the technology both as the focus of the lesson and as a pedagogical strategy for teaching students about the Global Positioning System(s).

8.6 Contributions to the Research Questions

RQ3. How do early adopters utilise geospatial technologies to enhance their geography teaching?

The teaching artefacts provided by Liam, Elizabeth, Eric and Russell demonstrate that these teachers are using geospatial technologies to provide their students with opportunities to engage in higher-order geographical thinking which challenges them to plan for and create new products that represent and transform their geography knowledge. All four teachers were able to integrate geospatial technologies into their learning activities and/or assessment tasks and in doing so were able to progress their students' thinking and learning beyond the mere recollection of facts. Instead, Liam, Elizabeth, Eric and Russell have adopted geospatial technologies to enhance their students' geography learning, developing learning activities that meet the higher levels of the adapted Bloom's Taxonomy framework offered by Anderson et al. (2001). Additionally, the analyses of the teaching artefacts show how these resources and their associated activities develop factual, conceptual and procedural geography knowledge.

In presenting the teaching artefacts from Liam, Elizabeth, Eric and Russell, this research has identified the high-quality practices utilised by these teachers in their respective schools. The work of these teachers, informed by their well-developed TPACK, provide high quality exemplars of how other teachers, including those teachers yet to adopt GST, could implement the technologies in their classroom. It is important to note that evidence from the *GST4GEOG* survey indicates that many early adopters are utilising geospatial technologies in less creative and less transformative ways. Of the 51 responses to the open-ended survey question asking teachers to describe their use of GST in geography teaching, 51% of responses (*n* = 26) described the use of GST for teaching geography content or learning activities that have traditionally been taught using paper-based maps or atlases. As these responses indicate, many early adopters may be using GST as an alternative to the atlas and, therefore, are potentially not taking advantage of the capacity of GST to encourage students' higher-order geographical thinking. The practices of Liam, Elizabeth, Eric and Russell, therefore, offer clear examples of how these teachers could further enhance their GST use in the classroom.

RQ1. What are the characteristics of early adopters of geospatial technologies in geography teaching in Australian secondary schools?

The teaching artefacts provided by Liam, Elizabeth, Eric and Russell also provide further evidence of the technological, pedagogical and content knowledge (TPACK) of these early adopters. In analysing each teaching artefact, evidence of the teachers' TPACK, particularly their specific focuses on technology, pedagogy and/or content, were evident in how teachers described and explained their approaches to planning and teaching their learning activities and/or assessment tasks. In each instance, when compared with each teachers' self-reported TPACK derived from their responses to the survey, analysis of their teaching artefacts closely aligned with their self-reported knowledge.

Each of the teachers was able to plan and teach learning activities and/or assessment tasks that demonstrate deep knowledge of how to combine geospatial technologies with geography content and appropriate pedagogies (TPACK). Additionally, each of the teachers demonstrated purposeful consideration of how technology can be used as a pedagogical tool to further students' learning (TPK). Knowledge of pedagogical strategies that can be used in combination with technology was clearly evident in teachers' explanations of how they designed learning activities and/or supported students to complete the tasks. Liam's commitment to implementing constructivist learning opportunities, for example, is further enabled by his use of Google MyMaps for student collaboration. Eric's production of video tutorials for his ArcMap-based activities are underscored by his understanding of how technology can be used to scaffold students' learning. Elizabeth changed her assessment task based on her understanding that geospatial technologies represented the most effective way for students to present their learning. Russell used smartphone geospatial technology to make geography learning relevant to students' lived experiences. Analysis of the teachers' artefacts serve as further evidence that high quality teaching with technology is predicated on teachers' knowledge of how technology can enhance the way that content is taught by teachers and acted on by students (TPACK).

8.7 Chapter Conclusion

This chapter primarily responded to RQ2. How do early adopters utilise geospatial technologies to enhance their geography teaching? Most of the teachers in the examples of practice outlined in this chapter incorporated authentic case studies, providing students with opportunities to explore real situations in local contexts which they could identify with (Hofman and Svododova, 2016) and also incorporated variants of problem-based learning in the teaching approaches that they adopted. (Pawson et.al.2006). There was some powerful learning (Hopkins, 2000) and powerful geography knowledge (Maude, 2018) in much of the practice that has been outlined. In a variety of ways, the participant teachers succeed in stimulating learning that is distinctively geographical. The teachers engaged students in relation to current debates on local, national and global issues, and used GST as a tool to apply geographical thinking to these issues. In practice such as that delineated here, GST is positioned "as an integral tool for teaching the skills and concepts of secondary geography" (Bowman, 2015, p. 1).

From the analysis of survey data, semi-structured interviews and teaching artefacts provided by Liam, Elizabeth, Eric and Russell, several conclusions can be drawn as to the ways in which early adopters make use of geospatial technologies in geography education.

First, results from the survey indicated that many teachers utilise geospatial technologies for traditional mapping tasks (such as learning country names, locations and for visualising distances between two geographical locations). While caution must be taken in assessing the results of the survey data, as limited scope was provided for teachers to describe how they approach utilising GST, the findings do indicate that, at present, many teachers are adopting GST as an alternative or replacement to atlases and printed maps. As such, the level of sophistication and complexity in these tasks appears to be limited.

Second, some early adopters are using geospatial technologies in creative ways that enable students to develop higher-order thinking skills and deep learning of geography concepts. As evidenced by the evaluation of Liam, Elizabeth, Eric and Russell's teaching artefacts, these early adopters draw on their strong technological, pedagogical and content knowledge (TPACK) to design and teach geography lessons that provide opportunities for students to engage with the cognitive processes associated with the higher levels of the adapted Bloom's Taxonomy framework described by Anderson et al. (2001). Most significantly, the teaching artefacts provided by Liam, Elizabeth, Eric and Russell include creative components, requiring students to plan and develop a new product (such as GIS/Google Earth layers representing their collection of geospatial data) to represent their learning of geography concepts and skills.

The analyses of the teaching artefacts showcased in this chapter lend weight to calls for the Bloom's Taxonomy to be brought into greater dialogue with discipline-specific knowledge and skills (Bijsterbosch et al., 2017). Specifically, the analysis demonstrated how teachers' inclusion of GST in their task design provided opportunities for students to both engage with higher-order thinking skills and to develop factual, conceptual and procedural geography knowledge. While the research for this study was conducted prior to the development of Bijsterbosch et al.'s (2017) geography knowledge-focused and adapted-Bloom's Taxonomy framework, this study does provide evidence to support the contention that higher-order cognitive processes and geography knowledge must both be considered when planning for meaningful GST-enhanced geography learning (Bijsterbosch et al., 2017, p. 18).

This chapter provided further evidence of how quality geography teaching with geospatial technologies is grounded in teachers' TPACK. Analysis of the teaching artefacts provided by Liam, Elizabeth, Eric and Russell demonstrated how these teachers enact their TPACK in the planning and teaching of their learning activities. The work of these teachers provides strong exemplars for how other teachers and those teachers yet-to-adopt GST could implement the technologies in the classroom.

The next chapter of this thesis continues this thinking, considering how early adopters of geospatial technologies can contribute to the widespread adoption of GST in schools through the ways they communicate with their teaching colleagues. Drawing on Rogers' (2003) Diffusion of Innovations theory, this chapter will highlight the critical role of early adopters in the diffusion of GST in Australian secondary schools.

Chapter 9

The Role of Early Adopters in GST Diffusion

9.1 Introduction

Context conditions influence how teachers use geospatial technologies in their geography teaching, including their capacity to act on their technological, pedagogical and content knowledge (TPACK). Consistent with the adapted TPACK context framework offered by Porras-Hernández and Salinas-Amescua (2013), macro, meso and micro level context conditions both enable and constrain early adopters in their use of GST in their geography teaching. The early adopters in this study, however, are able to draw on their strong TPACK to leverage the context conditions in their schools that enable geospatial technology adoption. As early adopters, these teachers have the skills and knowledge to be successful in their GST-enhanced teaching despite persistent barriers.

This chapter reports findings for RQ4. In what ways do early adopters promote the diffusion of geospatial technologies amongst other geography teachers? The purpose of this chapter is to identify the practices these teachers utilise to fulfil their role as early adopters in the diffusion of GST in schools. Drawing on Rogers' (2003) Diffusion of Innovations theory (DOI), this chapter considers the critical role that early adopters play in encouraging, supporting and enabling their teaching colleagues to adopt GST in their geography teaching. In particular, this chapter identifies the mechanisms or strategies that early adopters use to communicate the pedagogical potential of GST. In doing so, this chapter considers how other teachers who may not possess the same skills or knowledge as early adopters could be encouraged to adopt GST. This chapter particularly draws on data collected from Liam, Elizabeth, Russell, Melissa, Eric and John, who, in their actions both within and outside of their respective schools, are actively working to encourage widespread GST adoption amongst Australian geography teachers.

9.2 Early Adopters in the Diffusion of an Innovation

Rogers' DOI theory provides a framework through which to explore the role of early adopters in the diffusion of an innovation and, thus, how early adopters of GST work to encourage its widespread adoption amongst teaching colleagues. As established in Chapter Four, early adopters act as opinion leaders in the diffusion process. Opinion leadership is an "interpersonal communication and influence phenomenon" (Venkatraman, 1989, p. 53) whereby early adopters communicate with those yet to adopt an innovation. Early adopters form opinions about the relative advantage, compatibility, complexity, trialability and observability offered by an innovation and communicate these opinions to their peers. As these elements of opinion leadership are integral to Rogers' DOI theory and, therefore, to making meaning of this chapter, the definitions of these elements as outlined in Chapter Four are repeated here:

- *Relative advantage* refers to the extent to which an innovation (for example, a new product) is perceived by individuals in the social system as being better than a product – in this case a teaching and learning resource - that was previously used (Rogers, 2003). The greater the perceived relative advantage derived from the product, the more likely the product is to be adopted amongst relevant peers.

- The level of *compatibility* of an innovation with the existing values and prior experiences of the social system – in this case, a community of geography teachers – also determines the likelihood of an innovation being adopted and the rate and/or speed in which the adoption takes place. Rogers (2003) argued that innovations that are perceived to be most compatible with the social systems' existing values and experiences are likely to diffuse faster than those innovations that are less compatible.
- The extent to which an innovation is perceived as being easy or difficult to understand and use (*complexity*) influences the diffusion of an innovation. Rogers (2003) determined that "the complexity of an innovation, as perceived by members of a social system, is negatively related to its rate of adoption" (p. 257); that is, the more difficult an innovation is to use, the slower the adoption of the innovation will be.
- *Trialability* refers to the extent to which an innovation may be trialled or experimented with on a "limited basis" (Rogers, 2003, p. 258) before it must be fully adopted. In this instance, adopters 'try out' the innovation and reflect on the degree to which the innovation suits their needs. As Rogers (2003) argued, trialability is most relevant to earlier adopters of the innovation who ostensibly 'trial' the technology for their later adopting peers.

- The degree to which the success of the innovation can be observed (*observability*) affects the extent and speed to which an innovation is widely adopted. Innovations whose results can be more easily observed are likely to diffuse faster than innovations that are difficult to observe.

In his study, Rogers (2003) determined that the opinion leadership of early adopters is critical to the success of an innovation. Through communicating with their yet-to-adopt peers, early adopters work to reduce uncertainty about an innovation, highlighting the potential of the innovation and the benefits to be derived from its adoption. Additionally, Rogers (2003) determined that opinion leaders communicate three types of information to those yet-to-adopt an innovation: awareness knowledge, how-to knowledge and principles knowledge. As later described by Sahin (2006), awareness knowledge represents knowledge of an innovation's existence; how-to knowledge contains information on how to use an innovation correctly; and principles knowledge includes the functioning principles describing how and why an innovation works. Studies both in business and education contexts support the contention that opinion leaders' communication is of critical importance to the success of an innovation (see Baumgarten, 1975; Myer & Robertson, 1972; Venkatraman, 1989).

In this research, Rogers' DOI theory was used to examine the role of early adopters as opinion leaders in encouraging widespread adoption of geospatial technologies amongst their teaching colleagues and the mechanisms through which they communicate and/or demonstrate the relative advantage, compatibility, complexity, trialability and observability of geospatial technologies in geography teaching. As evidenced by the experiences of Liam, Elizabeth, Russell, Melissa, Eric and John, early adopters' explicit actions in communicating their opinions assuage their colleagues' uncertainties about adopting GST in their teaching.

9.3 The Diffusion Mechanisms of Early Adopters

In their interviews, the early adopters made a number of specific references to how they have helped other teachers both in their own school and in other schools to adopt GST in their geography teaching. To draw together these references and to analyse the mechanisms through which these early adopters promote GST diffusion, the analysis strategy described by Braun and Clarke (2006) was again used to identify themes within the teachers' interview responses. Three key themes (or mechanisms through which early adopters promote GST diffusion) were identified. The early adopters in this study *experiment with GST in their teaching and share their resources* with their peers, conduct *professional learning experiences* about GST in geography teaching for peers within their professional networks, and *exercise leadership* over curriculum in their schools and/or education systems. Through these experiences and professional activities, the early adopters communicate the benefits of adopting GST with their teaching colleagues and encourage, support and provide some of the conditions that allow other geography teachers to adopt GST in their own practice.

9.3.1 Experimentation and Sharing Resources

Through their own efforts to incorporate geospatial technologies into their geography teaching, the early adopters in this study have created and/or adapted, trialled and evaluated GST teaching resources in their own classrooms. A common theme amongst the early adopters was their propensity to take risks in their own teaching by using a range of different GST applications in the classroom and sharing the results of their experimentation with their teaching colleagues. Liam, in describing how he has developed his capacity to utilise GST in his teaching, stated:

Liam (p. 18, 480-489): Personally, I have been experimenting with things like Google MyMaps, Google Tourbuilder, Scribble Maps, things like that… so I haven't let it loose on the students yet. I've sort of had a couple of little testers with small groups just to see how they go. I just want to see this out, tell me how it works, tell me what you reckon…

Liam, in his experimentation, demonstrates a clear awareness that teaching with technology requires appropriate pedagogical planning (TPK). Using the technology with small groups of students, Liam has an opportunity to learn about how the particular applications work and their capabilities, how they are perceived by students and any pedagogical challenges that should be anticipated when using the technology with larger groups of students. As an early adopter, Liam explicitly references his desire to test out new software and approaches to geography teaching and is unperturbed by the potential challenges that could arise from his use of GST.

Liam fulfils his role as an early adopter in supporting his teaching colleague, with whom he co-teaches geography to two classes, to learn about the utility of the Google GST platforms for teaching geography concepts and skills. In his interview, Liam explained how he, in his own time, participated in the teacher professional learning modules offered by Google about the Google MyMaps platform. As Liam's colleague did not participate in the training, Liam explained how he shared with his colleague his opinion about the geography teaching opportunities that can flow from using Google MyMaps. In his subsequent GST-enhanced teaching, Liam provided technical and pedagogical mentoring for his colleague in implementing the technologies in the classroom. Consistent with the characteristics of early adopters determined by Rogers (2003), Liam's efforts to support his colleague in GST implementation reduced his colleague's uncertainty about adopting the technologies and provided an opportunity for his colleague to observe the benefits of the technology for geography teaching. In doing so, Liam communicated the *relative advantage*, *compatibility*, *complexity*, and *trialability* of GST for geography teaching to his colleague. Further consistent with Rogers' DOI theory, Liam, in his in-class support for his teaching colleague, communicated the awareness knowledge, the how-to knowledge and the principles knowledge that teachers require to be convinced to adopt GST. In this capacity, Liam makes a contribution to the diffusion of GST within his school context.

Elizabeth also experiments with different GST applications in her classroom and shares her experiences with more risk-averse teaching colleagues at her school and in her state's professional geography teachers' association:

> Elizabeth (p. 27, 651-662): I kind of experiment with the materials that are out there so that I can say to other teachers, "here, I've taken this idea and I've spiced it up a little bit, you could do this too." That sort of thing… the confident teacher will go, "oh yeah, I like that idea. I might come up with my own idea by doing this." The confident teacher will be able to do that. The less confident teacher will need somebody to say this works, we know it works, this is how you go about it.

Because of her strong technological, pedagogical and content knowledge for using GST in geography teaching, Elizabeth knows 'what works' and can foresee the potential of GST in enhancing her geography teaching. Elizabeth's strong appreciation of the potential of GST enables her to be resilient to comparative failures in her teaching.

> Elizabeth (p. 25, 602-608): There are a lot of teachers who are not confident, they don't want to learn, whatever their reason… I'm one of those teachers who are willing to try things and if it doesn't work, too bad. We'll go

> with the flow. If you're not willing to try something, to take a risk in case it goes wrong, then you're not going to try things.

Elizabeth's propensity to take risks in her teaching and her professional resiliency to failure are clear indicators of her TPACK; Elizabeth is able to implement and evaluate her teaching with technology, identifying how she could improve her approach to allow for future success. Like Liam, Elizabeth's risk taking allows her to fulfil her role as an early adopter by reducing her teaching colleagues' uncertainties about the complexity of implementing GST and its effectiveness for student learning in geography (thereby communicating the *relative advantage* and *compatibility*). In taking risks and by sharing her resources and opinions about the advantages and potential of GST, Elizabeth also shares her awareness-knowledge, how-to knowledge and principles knowledge about GST with other geography teachers. By utilising Elizabeth's resources, other teachers can experiment with GST with less risk of being unsuccessful (*trialability*). Elizabeth makes a contribution of the diffusion of GST at a state level as well as within her own school by sharing her resources with her colleagues in her geography teachers' association.

The predisposition of early adopters to experiment with an innovation and communicate the advantages, disadvantages and utility of the innovation with their colleagues is also reflected in Russell's efforts to encourage other teachers to adopt GST. Russell has invested significant time in testing GST applications, deliberating on their relevancy to the learning outcomes associated with *Australian Curriculum: Geography* and developing learning activities to share with other teachers. Russell created a website that includes exemplars of teaching practice, video reflections from students and their teachers on the impact of the technologies on students' learning and a guide for teachers to help them select the most effective GST application for teaching specific geography content or skills. Russell reflected on how the website works to decrease his teaching colleagues' uncertainty about the relevance of geospatial technologies in geography teaching:

> Russell (p. 28, 678-689): So how do we progress [the adoption of GST]? You've just got to chip away at it! Hopefully this project I've done is part of that process. Making what is possible immediately accessible and easy to follow and model it in curriculum application. Because, if you just get out and show people the technology, yeah, you're leaving them to make the connection between the technology and the application. Which doesn't work unless you're someone like me [who can] see the use as soon as you know what the technology does.

Through his design of the website and the associated resources, Russell shares his own strongly-developed technological, pedagogical and content knowledge (TPACK) with other teachers. The exemplars of practice, designed by Russell, demonstrate to teachers how GST can be integrated into geography teaching. Russell's teacher guide to the various smartphone geospatial technology applications acts as a means for Russell to communicate his positive opinion of geospatial technologies and the pedagogical applications of the technology to geography teaching. Through his website, Russell fulfils his role as an early adopter in encouraging other teachers to adopt GST. The inclusion on the website of videos of students and teachers discussing how they have used GST applications in the classroom works to reduce concerns about the *complexity* of the technology for teachers who have yet to adopt them. These teachers can observe the success experienced by other teachers (*observability*) and, in doing so, can increase their own confidence for implementing GST in their classrooms. Officially endorsed by the curriculum authority in his state, Russell's website reduces risk of failure for teachers by providing exemplars of successful GST-enhanced geography teaching (*trialability*). The materials on Russell's website provide all three types of knowledge for those yet-to-adopt GST: awareness knowledge, how-to knowledge and principles knowledge. Accordingly, Russell has an impact on GST diffusion at a state and national level via his website.

9.3.2 Providing Professional Learning Opportunities

Another commonality between early adopters in this study is their commitment to providing professional learning opportunities for their teaching colleagues to learn about how to integrate geospatial technologies into their teaching. Melissa, Eric, Elizabeth, and John were particularly explicit in describing how they have made purposeful efforts to share their knowledge about implementing GST in geography teaching with other teachers through professional learning. Particularly for Melissa, Eric and John, their capacity and inclination to offer professional learning for their colleagues is borne out of their own commitment to learning.

Melissa credits her Masters degree study as giving her the deep geography content knowledge that she needs to teach geography and to share that knowledge with her other teachers:

> Melissa (p. 1, 9-16; 22-25): I started teaching straight out of university – so a very long time ago! I was a SOSE method [but] history was actually my background… In 2013, I took time off and did a Masters in Sustainability which gave me access to a lot of geography subjects… One of the things I did do was a subject that was third year in spatial technologies which was really good… it helped me to at least feel a bit more confident about what spatial technologies were at the time.

Melissa's own learning has helped her to develop her geography content (CK) and her understanding of the relationship between geography topics and geospatial technologies (technological content knowledge (TCK)). Melissa's learning about GST applications provided her with the knowledge needed to apply GST to her own classroom and to share that knowledge with other teachers at a national conference of geography teachers. Melissa's presentation at the conference was an avenue for her to enact her opinion leadership about GST; her presentation demonstrated how geography teachers can successfully utilise Google Tourbuilder with their students to document and present their geography learning. In providing this professional learning opportunity for her peers, Melissa embodies the role of the early adopter in communicating with, encouraging and supporting other teachers to implement GST. Melissa's subsequent publication of an article in a teacher journal provides step-by-step instructions for creating a Google Tour, encouraging teachers to adopt Google Tourbuilder, whilst allaying concerns about whether it can be successfully implemented in the classroom (reducing *complexity* and providing *trialability* of the technology). Melissa's article clearly articulates the awareness knowledge, how-to-knowledge and principles knowledge that individuals need in order to be encouraged to adopt an innovation (Rogers, 2003; Sahin, 2006).

Similarly, Eric's attention to his own professional learning in geography has equipped him with the knowledge and proclivity to provide learning opportunities for other geography teachers. Eric participates in TeachMeet, a collaborative global professional learning series organised by teachers for other teachers. Eric's use of NSW Globe, the website for accessing public geospatial data provided by the NSW Government, started after he learned about the resource from another teacher at a TeachMeet event. Eric subsequently experimented with the NSW Globe data before conducting his own TeachMeet presentation about how to integrate geospatial technology in the classroom. Eric's attitude towards professional learning ("there's always stuff to learn" (p. 15, 356-361)) typifies that of the early adopter; through his own learning, Eric has equipped himself with skills and knowledge that have enabled him to become an opinion leader. In sharing his knowledge and experiences at TeachMeet, Eric enables other teachers in their GST adoption by decreasing uncertainties about the *relative advantage*, *compatibility* and *complexity* of GST in geography teaching. Eric's TeachMeet presentations enhance the awareness knowledge, how-to knowledge and principles knowledge of geography teachers who are considering adopting GST.

Elizabeth's role as a leader of her state's geography teachers' association sees her organise and present professional learning opportunities for geography teachers in her state. Elizabeth perceives that she has an obligation to support geography teachers, particularly those teachers who need encouragement to adopt GST.

> Elizabeth (p. 29, 700-711): I'm keen to run mentoring workshops… as an association, we need to be a go-to-place. "If I need help to know how to use this, who can I go to? Oh, I'll go to the Geography Teachers' Association. There's someone there that can help me learn how to do this." I think this is an important role that we play, that mentoring program. I think we have a big role to play in modelling what is possible. Support, offer workshops, all that.

Elizabeth's comments reflect how, as an early adopter, she is able to exercise opinion leadership about GST via her role in the professional teacher association. Elizabeth is able to demonstrate to other teachers, through her involvement in the mentoring program, that GST are relevant and achievable in geography teaching. By working with other geography teachers, Elizabeth provides opportunities for these teachers to observe how geospatial technologies can be used to enhance geography teaching (*observability*). The conferences and workshops that Elizabeth organises serve to reduce teachers' uncertainty about the *compatibility* and *complexity* of geospatial technologies.

Similarly, John, in his capacity as lead teacher at an environmental education centre, uses his skills and knowledge to support other teachers to adopt geospatial technologies. John visits schools as part of his teaching role to prepare students and teachers for their excursion to the national park. During these visits John communicates and demonstrates the value of GST for geography teaching and learning. John designs learning activities for students that incorporate the use of Google Earth and, in doing so, he provides support and resources for the teachers to take up these activities in their own teaching.

> John (p. 12, 286-294): We developed some student tasks which were focused on using laptops in the classroom… and the geography teachers, I think, were quite happy to have those things because they were local examples and they could point the kids at them and the kids could play with them.

John's comments further underline his understanding of the ways in which geography can be represented and taught using GST (i.e. John's TPACK) and his capacity to communicate that knowledge to other teachers. John experiences a high degree of agency as the principal of his centre and, as a result, has the ability to fulfil his role as an early adopter by providing teachers with on-the-ground support for using GST during his visits to classrooms. By demonstrating the use of Google Earth, John works to decrease the uncertainties of other teachers about how GST can be implemented in geography teaching. In leading GST activities in the classroom, John communicates the *relative advantage* and *compatibility* of GST for geography teaching, while also sharing the awareness knowledge, how-to knowledge and principles knowledge that teachers need to have to be encouraged and motivated to adopt GST.

9.3.3 Exercising Curriculum Leadership in Schools

The early adopters in this study hold some form of school or education system-related leadership position. These positions allow the early adopters opportunities to exercise agency over geography curriculum either in their own schools and/or across multiple schools in their education system. This leadership experience provides the early adopters with a range of mechanisms for communicating with other geography teachers and, accordingly, for sharing their knowledge and skills about the use of GST in geography teaching.

As Head of Geography at his school, Eric is able to exercise agency over the way in which geography is taught at his school. Eric's own interest and commitment to using geospatial technologies in geography teaching trickles down into how he expects teachers in his department to teach geography. As Eric reflected, "there are ten teachers in our department and I push the spatial stuff [and] professional learning" (p. 2, 45-47). Eric's 'pushing' of geospatial technologies is his articulation of how he, as an early adopter, communicates to his teaching colleagues the advantages to be derived from implementing GST in teaching (*relative advantage*). To reduce his colleagues' certainties about implementing GST, Eric designs and provides classroom-ready GIS databases and learning activities that can be used by all teachers in his school department. These resources reduce the *complexity* of GST and demonstrates its *compatibility* with geography teaching for teachers in Eric's school.

Elizabeth, in her leadership role at her school and through her work with the professional teachers' association, exercises her opinion leadership in communicating with teachers the application of GST to geography teaching. Reflecting on her first years of teaching at her current school, Elizabeth noted how she was able to design the school's geography subjects around her own perceptions of how geography should be taught.

> Elizabeth (p. 1, 47-51): [When I started at the school] I was pretty much the sole geography teacher. I got there and we were just going into Year 11 and there was an incredible amount of work that I had to do to set up senior school courses so I made my fieldwork a primary focus of what I did.

Elizabeth's focus on fieldwork has been sustained throughout her teaching career. As demonstrated in Chapter Eight, Elizabeth uses geospatial technologies to support students' learning during fieldwork activities. As the sole geographer at the time that she began her teaching at the school, Elizabeth was able to shape the school's future geography curriculum so that it was based on fieldwork, and by extension, the use of geospatial technologies. Through her curriculum leadership at the school, Elizabeth has provided the curriculum conditions that support teachers to adopt GST in their teaching, linking the use of GST to the school's focus on fieldwork in geography.

Similarly, Elizabeth's role within the geography teachers' association in her state affords her opportunities to promote GST to other geography teachers.

> Elizabeth (p. 8-9, 174-181, 190-209): At the moment, I'm currently working with our conference convenor to organise our conference for next May. I've also been instrumental in a number of PD workshops that we run throughout the year… My role [is] largely making sure we're offering PD opportunities. So that kind of thing. There's all the other bits and pieces that come with it, but primarily that's sort of my role, to oversee the putting in place strategies to help teachers becoming better teachers of geography.

In addition to conducting professional learning herself, Elizabeth, through her leadership in the GTA, plays a vital role in the diffusion of GST amongst other teachers by providing forums for interstate experts to present workshops to geography teachers. In this capacity, Elizabeth fulfils her role as early adopter; Elizabeth uses her leadership role to support other teachers, both in within her schools and state, in their learning about GST, its *compatibility* with geography teaching and how it can be implemented in the classroom (reducing *complexity*).

9.4 Diffusion of GST via Early Adopters' Communication

As evidenced by the professional activities and experiences of Liam, Elizabeth, Russell, Melissa, Eric and John, early adopters of GST play an integral role in its diffusion amongst teachers of secondary geography in Australian schools. By experimenting with GST in their teaching and sharing their teaching resources with their peers, conducting their own professional learning for teachers within their professional networks, and exercising curriculum leadership in their schools and/or education systems, early adopters communicate the relative advantage, compatibility, complexity, trialability and observability of GST as an innovation in geography education. Through these mechanisms, the early adopters in this study share their positive opinions about GST and, thus, actively work to support other teachers by decreasing their uncertainty about the merits of the technology and how GST might be incorporated into geography teaching. Figure 9.1 represents in diagrammatic form how early adopters, through their communication mechanisms, support the diffusion of GST amongst geography teachers.

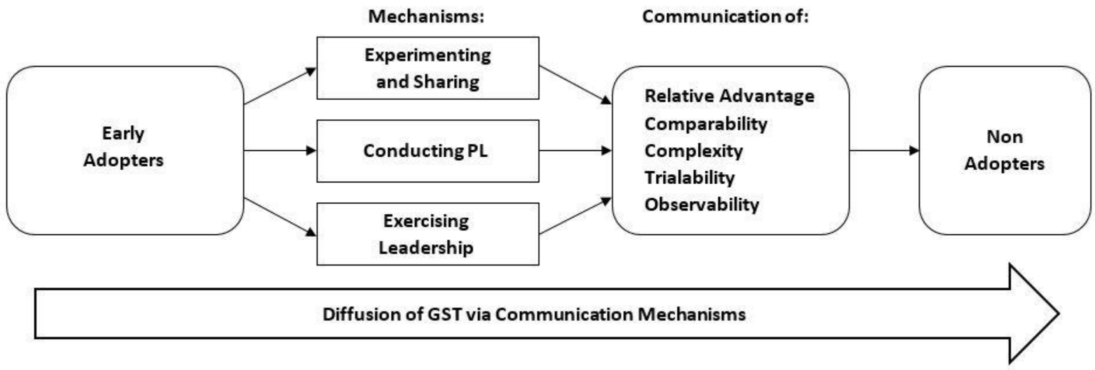


Figure 9.1. GST diffusion via early adopters' communication

In respect to the role of early adopters as opinion leaders, the findings of this study confirm the diffusion processes outlined in Rogers' DOI theory and other studies that have examined early adopters (Chau & Hui, 1998; Frattini et al., 2013). Through enacting their opinion leadership within their various professional networks and forums, the early adopters in this study communicate the three types of information needed by individuals who want to adopt an innovation: awareness knowledge; how-to knowledge; and principles knowledge. In essence, the early adopters in this study enable the GST-enhanced teaching practices of their teaching colleagues by sharing their knowledge of the existence of GST, how to operate GST and how it can be successfully integrated into geography teaching activities.

The early adopters' capacity to fulfil their role is made possible by their strong technological, pedagogical and content knowledge. Their well-developed TPACK is what enables them to foresee opportunities for GST to be used for teaching geography concepts and skills and, thus, helps them to appreciate the reasons why the technology is worth diffusing. Their knowledge of their students and how they can learn with technology makes them cognisant of the barriers and opportunities for GST-enhanced geography learning. Without their strong TPACK, these early adopters would not be able to share resources, facilitate professional learning or enact their curriculum leadership which appears to be essential for the diffusion of GST amongst geography teachers. It is their strong TPACK that allows these teachers to talk credibly to other teachers about the potential of GST and share their insights into the ways in which geography teaching can be enhanced with these technologies.

9.5 Early Adopters as Enablers of GST

The presence of an early adopter of GST within teachers' professional networks may act as enabling context condition for teachers to implement GST in their classrooms. In Chapter Eight, analysis of interview data from early adopters based on Porras-Hernández and Salinas-Amescua (2013) TPACK context framework revealed that a variety of macro-, meso- and micro-context conditions were found to influence teachers' capacity to adopt GST in their teaching. While the nature of these context conditions ranged from macro-level education policy decisions to micro-level teacher-directed pragmatic choices, a consistent theme throughout the interviews was early adopters' capacity to leverage context conditions that enable their GST teaching. It is possible that early adopters themselves act as enablers of GST at macro, meso and micro levels through their work in developing GST supportive curriculum (Elizabeth), providing professional learning opportunities (Elizabeth, Russell, Melissa, and Eric) and the technical and pedagogical support to their colleagues in their classrooms (Liam and John). While the focus of this study was to identify the mechanisms through which early adopters encourage the widespread adoption of GST amongst other geography teachers, further research is needed to validate the impact of early adopters at macro, meso and micro levels on teachers' capacity to implement geospatial technologies in their teaching.

9.6 Chapter Conclusion

This chapter argues that early adopters can play a role in improving the previously low GST adoption rate (Kerski, 2000; Baker & Langran, 2016) by prompting and enabling the diffusion of the technology in their schools/school systems. This chapter has provided insight into how early adopters, acting as opinion leaders about GST, communicate with other yet-to-adopt geography teachers in their professional networks and encourage and support them to learn about GST and how they can adopt them in their geography teaching. Drawing on Rogers' (2003) Diffusion of Innovations theory, this research ascertained the mechanisms that early adopters in this study use to communicate the relative advantage, compatibility, complexity, trialability and observability of GST in geography teaching. These mechanisms include experimentation and sharing of resources, providing professional learning opportunities for teachers in their professional networks and exercising curriculum leadership in their respective schools and/or education systems.

The findings presented in this chapter confirm early adopters' communication processes as determined by Rogers (2003). Critically, however, the findings build on Rogers' theory by demonstrating how early adopters' communication with teaching colleagues is made possible by their strong technological, pedagogical and content knowledge. The early adopters' TPACK gives them a critical understanding of how, when and why GST should be used in geography teaching (Mishra & Koehler, 2009). Early adopters then pass these understandings on to their teaching colleagues through the mechanisms described in this chapter.

The next chapter, Chapter Ten, is the final chapter in this thesis. Chapter Ten brings together the findings from Chapters Five through Nine to identify the key learnings, contributions and implications of this study.

Chapter 10

Conclusion

10.1 Introduction

When this research began, the implementation of *Australian Curriculum: Geography* had only just begun in some Australian states. Most notably, the New South Wales Government had yet to approach implementation. Other states, like Tasmania and South Australia, started teaching the curriculum at the beginning of that year (2014). When data were collected in 2015, most of the early adopters in this study had been teaching *Australian Curriculum: Geography* for eighteen months. Eric and Liam, as NSW teachers, were continuing to teach the state's previous Human Society and Its Environment curriculum, an integrated humanities/social studies curriculum framework.

Over the course of this study, geography teachers have undoubtedly become more familiar with the curriculum demands. Without an audit of how Australian teachers are teaching geography, however, it is not possible to make a judgement as to how many more teachers have taken up GST teaching practices during this time. While there continues to be a paucity of recent research about the use of GST in education in Australian contexts, recently published international studies still suggest that GST remains an under-utilised pedagogical tool for teaching (Baker & Langran, 2016). It appears that the 'problem' of GST implementation in geography teaching persists for many teachers, their schools and their students. The findings of this research, therefore, stand to make a critical contribution to understanding how geography teachers can use GST within the *Australian Curriculum: Geography* framework and the context conditions that influence (constrain/enable, encourage/discourage) teachers in their GST adoption.

The purpose of this chapter is to identify and synthesis the key contributions and implications of this study as they pertain to the research questions. It seeks to address 'so what?' questions relating to the research and link the findings from the study to bigger picture issues around GST in educational contexts. This study offers contributions related to the development of theory, practice and policy about the use of GST in geography teaching and ICT-enhanced teaching more broadly. This chapter identifies implications and recommendations for policy-makers, school leaders and classroom teachers. The chapter also outlines further opportunities for researchers to specifically examine GST adoption and GST-focused teaching practices.

10.2 Contributions of the Research

This study contributes to understandings about geography teaching practice, Australian curriculum policy and educational theory about teaching with technology. Foremost, in examining the 'problem' of GST implementation in *Australian Curriculum: Geography*, this research has brought to light some critical factors that make GST implementation more achievable for Australian geography teachers. These include the presence of early adopters in schools and the increasing capacity for teachers to make use of enabling context conditions that encourage GST adoption.

10.2.1 Identifying the Role of Early Adopters

A consistent argument made throughout this thesis is that early adopters are critical to the success of GST implementation within the *Australian Curriculum: Geography* framework. The findings of this study confirm that early adopters are at the forefront of efforts to 'diffuse' GST in schools. Early adopters provide reassurance and support for those yet-to-adopt (Rogers, 2003). Through their own successful GST-focused geography teaching, early adopters believed that they illustrated to other teachers that GST tools are curriculum-relevant and accessible, and that the implementation of the technologies is achievable for teachers.

Early adopters of GST in this context of this research were generous professionals. Early adopters possess strong personal TPACK which enables them to create teaching resources which benefit their own students, but which also can be passed on to those yet-to-adopt. Teachers yet-to-adopt GST can make direct use of these resources or adapt them to suit their own teaching approach or classroom setting. The resources produced by early adopters can be relied upon – early adopters' success in the classroom, their passion and enthusiasm for GST, and their willingness to share provides a level of safety for less confident teachers, and an assurance that they too can be successful in using the technologies in their teaching. Leading professional learning opportunities, mentoring colleagues and engaging with professional teacher associations are some of the ways in which early adopters support, encourage and assist other teachers in GST adoption.

This study has found that the role that early GST-adopting teachers play in supporting colleagues' GST implementation is consistent with that theorised by Rogers (2003). While the congruence of the findings of this research with Rogers' theory is explored in greater depth later in this conclusion chapter, a distinct finding of this research is that early adopters can be successful in harnessing the learning potential of GST without having to engage themselves or their students in using complex GIS systems requiring specialist levels of knowledge to understand and operate. This finding is significant as the research literature published over the last decade has consistently focused on either describing the potential for GIS in education or implementing and evaluating researcher-led or researcher-designed GIS intervention studies (see, for example, Britz & Webb, 2016; Jadallah, 2017; Singh, Rathakrishnan, Sharif, Talin & Eboy, 2016). GIS remains the gold standard for GST education researchers, despite the many published studies that repeatedly demonstrate the persistent barriers to its implementation (see Artvinli, 2017; Hong, 2016; Hong & Melville, 2017). The early adopters in this study indicated through their practice that knowledge of complex professional-grade technology (and the subsequent teaching of that knowledge to students) was not necessary to make effective use of GST for teaching and learning secondary school geography. Indeed, early adopters demonstrated to their colleagues that deep geography learning is possible using simpler, much more accessible GST applications. This finding is confirmed through the analysis of early adopters' teaching artefacts in Chapter 8, which demonstrates that the teachers' use of relatively simple GST still enabled sophisticated, 'higher-order' representations of students' geography learning.

In summary, a key contribution of this study is to illustrate the importance of early adopters in supporting their colleagues to implement this new curriculum requirement. In fulfilling their role as early adopters, these teachers provide the necessary support to other teachers to enable them to adopt GST. Thus, it is imperative that early adopters are provided with license to communicate and share with their colleagues. Schools, education departments and other professional networks should consider the value in allowing early adopters the opportunity to experiment and share resources with colleagues, time to design and conduct teacher-led professional learning and to exercise curriculum leadership in their spheres of influence. Early adopters model for their colleagues how simple GST applications can be used to great effect in the secondary geography classroom. The early adopters in this study showed great willingness to encourage and support their colleagues with GST adoption and it would be good policy to encourage further opportunities from them to continue this work.

10.2.2 Identifying Enabling Context Conditions

Barriers to teachers' use of GST have been examined by other researchers (see Baker, 2005; Kulo & Bodzin, 2011; Wheeler et al., 2010, for example), however, the length of time since these studies (and the subsequent changes in the technological, social and educational landscape in which teachers live and work) was the impetus for further research into the conditions that influence teachers' GST teaching practices. Much of the existing GST education research speaks to deficits: deficits in teachers' knowledge (Bednarz & van der Schee, 2006; Demirci, 2008), deficits in technology provisions (Bednarz, 2004; Hong, 2016; Kerski, 2003), and deficits in teachers' motivation and interest in changing their pedagogical practices (Höhnle, Mehren & Schubert, 2015; Hong, 2015). While this research was concerned with establishing whether these barriers persist in contemporary Australian geography classrooms, it also aimed to speak back to the deficit-thinking that is evident in GST education research by identifying enabling conditions that support early GST-adopters' innovative pedagogies. This study identifies *possibilities* for teaching and GST adoption, rather than merely reporting the obstacles.

While some barriers certainly do persist, including the cost of technology and limited technology access for some teachers (consistent with findings from Beeson (2006), Lam et al. (2009) and Yap, et al. (2008), there is greater cause for optimism about GST adoption in contemporary Australian classrooms. Indeed, a key finding of this research relates to the potential for increased GST-enhanced teaching and learning as a result of Bring-Your-Own-Device (BYOD) school policies that enable teachers to make pedagogical use of students' own technology resources in the classroom. Smart-phones with GPS capabilities and web-based GST applications that are compatible with iPads and other mobile devices offer considerable opportunities for Australian geography teachers to leverage the technology access that these devices enable. Encouragingly, and since this research began, it appears that GST education researchers are beginning to recognise the opportunities these technologies present for geography teaching and learning (Fargher, 2018).

Analysis of teachers' interview data made clear that there are plenty of enablers of teachers' GST teaching practices. By employing Porras-Hernández and Salinas-Amescua's (2013) TPACK-context framework, it becomes evident that enablers of GST teaching are present at all 'levels' (macro, meso and micro) of teachers' working contexts.

Macro context enablers include enhanced public access to geospatial datasets maintained by local governments, non-government organisations and the Australian Government (see data.gov.au, for example) and improved commercial access to GST applications on smart-devices and other GPS and/or Internet capable personal devices.

Meso context enablers included BYOD policies and the support of professional geography teaching associations in facilitating professional learning and making GST resources available to teachers.

Micro context conditions included the ease in which students can understand and use simple web-based GST applications that teachers can more readily adopt in their practices.

The increasing presence of these enabling conditions and early adopters' awareness and capacity to adopt GST in response to these enablers offers hope for further adoption amongst Australian geography teachers. If early adopters can mitigate the barriers and leverage enabling conditions in their own practice, they can support and assist their yet-to-adopt colleagues to do the same.

Therefore, a key finding of this research is that there are many context conditions present in the contemporary Australian educational landscape that can be seen to enable GST adoption. This research signposts those context conditions that, when leveraged by teachers, can further enable themselves and their colleagues to adopt GST for geography teaching. An important contribution of this research relates to making teachers and schools aware of these context conditions and advocating for teachers to be given agency to harness the opportunities these conditions present for GST-enhanced teaching.

10.2.3 Advancing Theory

This research also makes an original contribution to the theoretical literature regarding teachers' use of technology in teaching. This study extends understandings of the process through which curriculum innovations can become more widely adopted. These contributions relate to nuancing the TPACK framework (Mishra & Koehler, 2006), the Diffusion of Innovations theory (Rogers, 2003), and furthering the GST education research field.

TPACK. This study lends weight to arguments that the TPACK framework must include due reference to the issue of context in explaining and understanding teachers' knowledge for teaching with technology (Blackwell, Lauricella & Wartella, 2016; Phillips, Koehler & Rosenberg, 2017). Although context has been an acknowledged component of the TPACK framework since Mishra and Koehler's (2009) redesign, there remains limited research investigating context conditions that influence teachers' TPACK in subject-specific contexts. Employing Porras-Hernández and Salinas-Amescua's (2013) TPACK-context framework, this study identified a range of macro, meso and micro context conditions that commonly influence the early adopters in this study. In doing so, this study adds to the theoretical complexity of the quantitative TPACK framework in developing qualitative descriptions of the influence of context on teachers' GST adoption.

Diffusion of Innovations theory. Consistent with Rogers' (2003) articulation of the Diffusion of Innovations theory (DOI), this study found that early adopters play a vital role in driving the widespread adoption of GST amongst other geography teachers. Early adopters in this study, through the communication mechanisms that they employ, demonstrate the relative advantage, compatibility, complexity, trialability and observability of the technology to their colleagues who are yet to adopt GST in their teaching. This research advances the application of DOI theory by exploring the context specific communication mechanisms that Australian GST early adopters use to support their colleagues: experimenting and sharing teaching resources, conducting professional learning opportunities and exercising curriculum leadership in schools.

Furthermore, this study has brought together the TPACK framework and DOI theory to provide a greater understanding of the practices and experiences of GST early adopters. The early adopters' capacity to fulfil their communication role is made possible by their strong technological, pedagogical and content knowledge. Through their well-developed TPACK, as enacted in their own teaching practices, the early adopters in this study demonstrate strong understanding of how, when and why GST can be used in geography teaching, and then communicate these reasons to other teachers.

GST education research. As previously delineated, this research draws attention to enablers of practice which have emerged more recently in response to the increased commercialisation of geospatial technologies, open access data policies and other factors. Thus, this research marks a shift in thinking in GST education research from barriers and challenges to opportunities and possibilities.

This research also answers the call made by Baker et al. (2015) for further GST education research that is strongly grounded in social science research methodologies with clear connection to educational literature. This mixed-methods research study has been carefully conducted with attention to the methodological principles of quantitative and qualitative research, while the research problem and research questions were generated in response to an extensive review of the existing GST education research.

In sum, through this research, the TPACK and DOI theoretical models are further elucidated, illustrating how each of the models can be used to explain how context conditions can enable GST adoption and the role of early adopters in the ‘diffusions’ of these technologies. This research also contributes to GST education research, shifting the focus of such research from preoccupations with barriers to more of a futures-thinking focus relating to possibilities and opportunities.

10.2.4 Enhancing Teacher Practice

This study, in examining the practices and experiences of early adopters of geospatial technologies, has shed light on the pedagogical approaches to GST-enhanced teaching utilised by early adopters. As demonstrated through an analysis of early adopters' 'teaching artefacts' in Chapter Eight, the skilful and purposeful application of GST in teaching can engage students in higher-order thinking and geographical knowledge and challenge them to envision new ways of representing their geography learning. Evidence presented in Chapter Eight illustrated how the early adopters' use of GST in their geography teaching activities enabled students to develop factual, conceptual and procedural geography knowledge. For these early adopters, GST are not a last minute 'add on' to the learning task. Instead, geographical inquiry is at the core of these early adopters' planning. The technology is a tool for enabling geographical inquiry. The use of GST is not merely for demonstration or engagement purposes, but for powerful geography learning.

The teaching artefacts shared by the early adopters in this research demonstrate how GST can be made an integral component of geography teaching and geographical inquiry in the Australian secondary school. A persistently reported barrier to teachers' GST implementation is a lack of subject-specific resources for teachers to use in their own practice (Tan & Chen, 2015). This study, in seeking to emphasise the future possibilities of GST education, provides these artefacts as exemplars of practice that can be used by geography teachers wanting to use GST in their teaching. The artefacts, kindly supplied by the early adopters for dissemination in this research, are presented as such a way that teachers can use them in their entirety or adapt them to their contexts and needs.

In providing these artefacts and their accompanying analysis, this research lends further legitimacy to the use of geospatial technologies in school geography teaching. While researchers are continuing to gather evidence as to the effectiveness of GST instruction on students' geography learning (see, for example, Britz & Webb, 2016; Demirci, 2015; Jadallah, 2017), this study demonstrates that GST can be used to engage students in higher order geographical thinking. It is hoped that this finding will go some way towards alleviating teachers' concerns about the value of GST in geography teaching (Höhlne et al. 2013), while actively encouraging geography teachers to consider the opportunities that GST presents for their students.

10.3 Recommendations

10.3.1 Recommendations for Policy

In exploring the practices and experiences of early adopters, the impact of context on teachers' capacity to teach geography with GST was firmly established. Persistent barriers were found that will need to be addressed if GST is to become a widely adopted pedagogical practice in Australian secondary school geography. To this effect, the following recommendations are made:

- Foremost, the ambiguity regarding the place of geospatial technologies within *Australian Curriculum: Geography* must be clarified by curriculum-makers to help support geography teachers in their appreciation of how and when GST can and should be used in their classroom teaching. As demonstrated in Chapter Two, GST appear in *Australian Curriculum: Geography* content descriptors and content elaborations across the Years 7-10 framework. Despite this, curriculum references to GST are often accompanied by the qualifiers "as appropriate" or "with or without spatial technologies." This equivocal language may be working to constrain teachers' adoption of GST in two ways. First, these qualifying causes may be interpreted as a 'get-out' clause by those teachers who are reluctant to change their long-standing geography pedagogies. Second, if *Australian*

Curriculum: Geography does not explicitly demand GST use of geography teachers, then teachers may not feel empowered to push for the context conditions that support adoption in their schools (e.g. school administration support, resource funding, etc.). This research therefore recommends stronger language be incorporated into *Australian Curriculum: Geography* to categorically embed GST in the curriculum.

- A key enabler of early adopters' practice was found to be the increasing availability of geospatial datasets published online by local, state and national governments. The Australian Government's data.gov.au repository allows early adopters (and other members of the public) to search for relevant geospatial datasets that can be used in teaching. Similarly, local and state government websites (such as the Tasmanian Government's LISTmap (thelist.tas.gov.au)) and Victoria's Data.Vic (data.vic.gov.au)) provide public access to locally collected geospatial data. The open access data policies that sit behind these initiatives particularly address barriers to teachers' GST adoption, such as the lack of local geospatial datasets and teaching resources (Fleischmann, van der Westhuizen & Cilliers, 2015; Tan & Chen, 2015). This research recommends the continuation of these open access data policies and further increases in the depth and scope of datasets published online. Additionally, given the usefulness of these online data repositories for teaching/education, the development of educational resources to accompany these datasets would further support teachers' use of the data.

10.3.2 Recommendations for School Leaders

While not all school principals have responsibility for hiring decisions in Australian secondary schools, many of these school leaders have the capacity to shape their school's teaching priorities (Gavin & McGrath-Champ, 2017). Principals can make purposeful decisions about staffing, identifying and supporting those early-adopting teachers that have the knowledge, skills and confidence to embed geospatial technologies in their teaching. As demonstrated in this research, these early adopters can support and encourage other geography teachers to be more innovative in their practice. Principals' identification and support of early adopters of GST would help to promote the diffusion.

Similarly, school leaders (including principals and department heads) have authority for making school-wide curriculum decisions. The development of a cross-school approach to GST implementation could empower individual teachers to experiment with geospatial technologies in their teaching and/or work collaboratively to develop effective teaching materials. School leaders should exercise their influence in shaping context conditions that allow early adopters to fulfil their role in the diffusion of GST; for example, allowing sufficient time and resources for early adopters to provide professional learning or mentorship for their geography-teaching colleagues.

10.3.3 Recommendations for Teachers

The research findings demonstrate that further teacher professional learning will be necessary for supporting and enabling geography teachers to adopt GST. This research has drawn attention to avenues for professional learning that teachers can pursue:

- Membership of professional associations. The experiences of early adopters in this study illustrate how various state-based geography teacher associations provide support for GST implementation.
- Attendance/participation in early adopter-led professional learning events (such as TeachMeet and teacher conferences). Early adopters were found to lead professional learning for their peers via these forums.
- Establish collaborative networks for teaching. Collaborative networks of teachers share resources that have been used effectively with students.

10.4 Opportunities for Further Research

As is unavoidable within the limited scope of a PhD study, there are certain limitations of this research. While all efforts have been made to mitigate the impact of these limitations on the research findings, these limitations bring to light opportunities for further research in this area.

10.4.1 Limitations

It is important to acknowledge the limitations of this study when considering the research findings. These limitations include:

1. Participant self-selection. The recruitment of research participants via an initial online survey resulted in teachers self-selecting to participate in the research based on their own interest in the topic and their past experiences of teaching with GST. While participant self-selection means that the researcher does actively control who participates in the research (Bethlehem, 2010), the distribution of the web-link to the online survey via

emails to school principals and geography teacher associations ensured that those who received the survey and ultimately participated were from the targeted population (early adopters of GST). Qualitative evidence collected in this study further confirms that early adopters of GST were the participants in the research.

2. Relatively small sample size and limited accessibility of participants. When working with small populations (such as early adopters of GST), research designs that incorporate quantitative research methods are inevitably challenging to execute. Observance of the assumptions of the quantitative research paradigm necessitates an understanding that small sample sizes can yield unreliable statistical results (Button, 2013) and, therefore, it is inappropriate to conduct complex statistical tests with a small sample size (Hoelter, 1983). A greater sample size in this study would have, for example, allowed for confirmatory factor analysis of the TPACK domains and further critical evaluation of the framework. Due to the small sample size, the use of descriptive statistics was favoured so as to not inflate or over-estimate the predictive power of the data.
3. Teacher diversity in experience and context. As is to be expected, the early adopters in this study reported varying levels of GST implementation. During both the quantitative and qualitative phases of this research, early adopters communicated varied experiences of adopting GST and spoke to different context conditions that influence their teaching. The outcome of this diversity of experience and contexts is that generalisations about early adopters must be critically considered. Indeed, even within those early adopters who participated in the qualitative phase, clear differences existed

in teachers' experience and school contexts. Some of these early adopters described teaching in school contexts where technology access did not hinder their pedagogical decisions and in which their students' academic achievement levels are above or substantially above the national average. The experiences of these teachers were in significant contrast to those experienced by other early adopters, such as Sarah, who teaches in a school with limited technology resources and with students currently achieving below the national average in the NAPLAN assessment. Inevitably these context differences account for some of the differences in the early adopters' practices, with those teachers with greater technology and resource access demonstrating more high-level GST teaching practices in their teaching artefacts. As a result, this research unavoidably presented a greater focus on those teachers with more advanced levels of practice but acknowledges that not all early adopters implement GST to the depth of those featured in this study for a variety of reasons.

10.4.2 Further Research Projects

In response to the limitations of this study, a range of further research projects about early adopters of GST have been identified. These opportunities include:

- A large-scale quantitative research study of all teachers' knowledge and confidence for teaching with geospatial technologies. Due to challenges related the limited scope of this PhD research and its focus on early adopters, it was not possible (nor necessary) to conduct a large-scale national study of all teachers. Participants from this study were largely drawn from New South Wales, Victoria, South Australia and Tasmania. A national study of all teachers would allow for a greater appreciation of the influence of context on teachers' TPACK and GST use and would allow for an examination of the practices of teachers with varying levels of GST expertise. This research would be particularly useful for identifying any state-based differences between contexts, within geography teachers' TPACK and their use of GST. Given the staggered implementation of the *Australian Curriculum* across Australian states and territories and the different pre-*Australian Curriculum* frameworks that preceded the current curriculum, there might prove to be further differences in teachers' GST adoption worth exploring.

- Observational research. In this study, early adopters' practices of teaching with GST were identified through an analysis of their teaching artefacts. Future opportunities exist to conduct observational research to confirm the means in which teachers implement GST in their geography classrooms with their students.
- Further research in less well-resourced schools**.** One of the limitations of this research related to the limited number of participants recruited from schools that possess less technology resources. Only one teacher, Sarah, reported having limited access to technology in her school. Sarah's comments about the context conditions that influence her TPACK and GST-enhanced teaching were found to often contrast with those experienced by teachers in schools with greater technology resourcing. Specifically, Sarah spoke to a wide range of meso and micro context barriers to her GST adoption, including unreliable technology access and a lack of school administrative support. Results from the *GST4GEOG* survey, however, confirm that limited technology resourcing is a

continuing issue for many early adopters. As such, further research should be conducted to confirm the different context challenges and enablers between schools and to consider what should be done to improve GST use in less well-resourced schools.

- Further research about teachers' use of Google platforms and other simple web-based GST. This research demonstrated that early adopters are confident in their capacity to teach geography with the Google mapping platforms and other simple web-based GST. This stands in stark contrast to their reported low level of confidence for teaching with GIS. This finding is consistent with previous research that indicates that teachers lack confidence in teaching with complex GIS software (Wheeler et al., 2010). Many of the recently published GST education intervention research studies focus on student and teacher use of professional GIS software. As it currently stands, there exists limited longitudinal research demonstrating an on-going impact of GIS intervention on teachers' pedagogical approaches. Thus, it is proposed that future research should also focus on opportunities to develop teachers' capacity to teach with these simpler web-based platforms. Indeed, it appears that GST education research may already be heading in this direction (see, for example, Collins, 2017; Hsu, Tsai & Chen, 2017; Jarvis, Kraftl & Dickie, 2017).

10.5 Concluding Remarks

Beyond the specific context of geography education, knowledge of geospatial technologies and geospatial technology applications and platforms matters for current and future human populations. A range of publications and research studies in the past five years outside the realm of education have underlined just how important geospatial technologies can be – and will be – in influencing how humans plan for some of the most significant challenges of the twenty-first century. Areas of GST application include subject matter as diverse as: ground water mapping in the developing world (Prabhu, Sivakumar & Rasayan, 2018); land-site suitability evaluation for new crops (Das, 2014; Gahlod et.al, 2017); detection of shoreline change (Manjulavani et.al. (2017); urban growth assessment and prediction (Saxena & Jat, 2017); landslide and flood susceptibility (Lai, Tsai & Chiang, 2016; Lawal, 2014) and the documenting of archaeological sites ahead of rising sea levels (McCoy, 2018). Concomitantly, teaching and learning about the importance and uses of geospatial technology also matters.

This thesis began by identifying the 'problem' of geospatial technologies within the *Australian Curriculum: Geography* framework. Given the significant value of geospatial technologies as tool for analysing some of the world's most pressing social and environmental problems (see Lagmay, Racoma, Aracan, Ayco & Saddi, 2018; Rubio, Rubio & Abraham, 2018; Sahara, Sarr, Van Kirk & Jules, 2015), the challenges associated with teaching and learning about GST within the national curriculum framework ought to be a cause for concern for teachers, schools and policy-makers. These challenges include limits on technology access and school support and teachers' professional knowledge, in addition to the high cost of some GST hardware. Many of these challenges were first identified in the Australian context by Wheeler et al. (2010) and, as indicated by the findings of this study, still appear to be problematic for today's teachers. While Australian geography educationalists have spoken of the potential usefulness of GST for teaching since the early 2000s (see, for example, McInerney, 2002; West, 2003), the situation remains, at the end of this research in 2018, that the capacity of teachers and schools to adopt GST for purposeful and meaningful geography education is still hamstrung by some significant challenges.

Given the persistent barriers to teachers' GST implementation, it appears likely that many teachers may still be reluctant to introduce GST into their teaching repertoire. If so, many Australian school students may miss out on the opportunity to come to know, understand and learn how to use geospatial technologies in ways that help them to appreciate and analyse the many problems plaguing both the contemporary and future world. From a vocational and future employment perspective, this may further contribute to the downward trend in Australia's spatially-literate workforce and the on-going paucity of Australian qualified spatial scientists (ACIL Tasman, 2013; Lawrence, 2011). From a global citizenship perspective (Ibrahim, 2005; Lynch, 1992), limited opportunities for students to engage with spatial patterns and trends (for example, patterns of global poverty, habitat and biodiversity loss) may preclude some students from developing an understanding of these acute global issues and constrain them from appreciating their responsibilities as global citizens. As such, limited GST implementation in schools could have far-reaching consequences beyond the failure to meet a curriculum requirement.

The contribution of this study in investigating the GST-enhanced teaching practices of early adopters has provided not only useful exemplars for teachers and schools looking to implement GST in geography teaching, but also has enabled qualitative insight into the extent to which Australian teachers are currently using geospatial technologies to create meaningful and purposeful geography learning experiences for students. The analysis of the practices of early adopters has yielded causes for optimism about the current opportunities some Australian students have to engage with GST as part of their geography education and the future opportunities that may arise as the geography teaching workforce become more skilled at using GST in the classroom. The early adopters in this study demonstrated an awareness of the possibilities that GST present for geography teaching. While the complexity of teachers' uses of the technologies varied, each of the early adopters were able to design learning activities that appropriately brought together relevant GST applications and platforms, curriculum content and geography pedagogies to provide students with opportunities to *learn about* and *learn with/through* geospatial technologies. This accords with the central of line of argument within some GST education studies which recommend that students be given opportunities to learn both the technical skills needed to operate GST applications and the capacity to use GST as a tool for developing their subject content knowledge (Sui, 1995; Baker et al., 2015).

In this study, the analysis and discussion of the early adopters' teaching artefacts reflected a continuum of complexity in the depth and manner to which the teachers made use of GST in the classroom. Liam, for example, had students use Google MyMaps to plot place locations. This activity both demonstrated Liam's knowledge of Google MyMaps as a platform for visualising geospatial data, but also enabled his students to develop basic technical skills in operating the technology through the simple geography learning task. Elizabeth further developed her students' geospatial skills by having them input data they had collected during their geography fieldwork assessment task into Google MyMaps. Eric demonstrated the most sophisticated use of GST in his requirement for his students to use ArcMap GIS to analyse the spatial distribution of economic and social variables across Sydney suburbs. While the early adopters' teaching artefacts all linked relevant geography content with appropriate geospatial technology applications and platforms, in this study only Eric realised the potential of GST as an analytical tool within his teaching practice. This finding suggests that the value of GST as a pedagogical tool for teaching students to analyse and interpret geospatial data has yet to be fully realised in Australian geography classrooms. Further research in this field and, subsequently, further research-informed professional learning opportunities for geography teachers, will be needed if GST is to flourish as a pedagogical and analytical tool within the geography classroom. Without this, there is potential for GST, even if it is more widely adopted amongst teachers, to remain predominantly a tool for displaying geospatial data, rather than it being used to enable higher-level geographical analysis by students.

This study has suggested that GST early adopters, through their communication with their colleagues, could contribute to the realisation of the widespread GST adoption within Australian secondary schools. In line with Rogers' (2003) conception of the 'early adopter', the teachers in this study support and encourage their colleagues to adopt GST and provide them with tried-and-tested teaching resources to make implementation easier. In the Australian context, there has been a significant gap in time between the first 'innovators' trialling GST and early adopters then implementing the technologies in their teaching (Kidman and Palmer first studied Australian GST innovators in 2006). This has also coincided with a distinct lack of attention paid within the research literature to how Australian teachers have used GST since this time (Kinniburgh (2008) and Wheeler et al. (2010) being notable exceptions). If the case of GST adoption amongst teachers is in keeping with Rogers' (2003) Diffusions of Innovations theory, the communication work of today's early adopters of GST will – in theory – soon lead to the 'early majority' of teachers adopting the technologies in future. As the link between the very early adopters and later-adopters, the early majority also play a key role in the diffusion process. Early majority adopters take longer to adopt an innovation (Ram & Hung, 1994) but, according to Rogers' theory, willingly follow innovators and early adopters in taking up an innovation (Rogers, 2003). Early adopters matter, but a broader professional consensus is the key to ensure that innovations take root.

Given the considerable length of time that has elapsed between Australian geography educators like Malcolm McInerney (2002) and Bryan West (2003) signalling the potential of GST within geography education and their adoption by teachers such as the early adopters in this study, a key question raised in response to this study is: what needs to be changed or improved for GST to resonate with more teachers than it currently does? This study offers some possible strategies for enhancing both willingness of teachers and schools to adopt GST and their opportunities to do so. As mentioned in the previous section of this chapter, the language in the curriculum with respect to the role of GST in geography teaching and learning (that is, GST appears within some of the mandatory 'content descriptors' but more of the optional 'elaborations') may lead some teachers and schools not to see GST as a priority. This problem may be further exacerbated by the depth and range of content knowledge that must be taught within the *Australian Curriculum*. Indeed, curriculum reviewers have suggested that the *Australian Curriculum* is 'overcrowded' with too many competing objectives and priorities (Department of Education, 2014). It is possible that less equivocal curriculum language could better draw attention to the value of geospatial technologies within geography education and signal to teachers and schools that GST adoption is a relevant and worthwhile financial and pedagogical investment. If this equivocal language continues within the curriculum, there is a possibility that the opportunity to make GST a widely-utilised pedagogical tool for geography teaching will not be realised.

The analysis of survey data collected in this study indicated that access to technology in schools remains a critical factor in influencing teachers' decisions to adopt GST within teaching. This finding suggests that, despite significant federal government expenditure on technology infrastructure in schools over the past decade, the availability of technology for teaching purposes still presents a considerable challenge to both GST implementation and technology-enhanced teaching more broadly. This study draws attention to how Bring-Your-Own Device (BYOD) policies, and the mobile devices that students bring to class because of these policies, can positively influence teachers' capacity to implement GST and their pedagogical decision-making about how they will teach with the technology. The presence of student-owned mobile devices helped some of the early adopters in this study to circumvent the challenge of limited technology access. While this finding suggests that schools with active BYOD policies may be able to harness this context condition to enable greater implementation of GST in the classroom, it is concerning that there have been moves in some education communities to remove these technologies from schools. In Tasmania, a high school principal has recently expressed concerns about the distracting effects of mobile technologies in the classroom and implemented a 'ban' on such devices in his schools' classrooms (Costello, 2018). In New South Wales, the Department of Education (2018) is currently reviewing the use of mobile digital devices in schools amid concerns about their use for cyberbullying and other dangers young people can experience online. The research literature also appears similarly divided about the cost and benefit of mobile devices in schools. Some studies have argued that BYOD policies positively impact students' learning (Bruder, 2014), with others suggesting that technology can sometimes lead to student distraction from learning (Kay, Benzimra & Li, 2017; Santos & Bocheco, 2016). The implication of decisions to abolish BYOD policies or to remove mobile devices from classrooms could well have flow-on effects for teachers' GST adoption. The removal of this technology from schools could hamper the efforts of innovative geography teachers in implementing GST, while also signalling to those teachers yet-to-adopt that the use of technology in teaching is not valued by the administrators of their school/school system. As some of the participating early adopters in this study reported difficulties in accessing technologies for geography learning, it is possible that removing BYOD policies and mobile devices from schools could lead to these teachers (and their colleagues) having fewer opportunities to enhance their geography teaching through the application of GST and ICT more broadly.

Principally, this thesis has been a study of teachers' implementation of GST within geography education. However, the study's findings related to teachers' use of technology in teaching raise broader questions about the enactment of ICT-enhanced teaching and learning in Australian schools. There is a plethora of Australian policy initiatives aimed at increasing and improving students' ICT capabilities. Two recent examples of such initiatives are the publication of the new digital technologies curriculum (*Australian Curriculum: Digital Technologies*) (ACARA, 2015) and the Australian Government's *National Innovation and Science Agenda* (Department of Education and Training, 2015) which allocated $64 million of federal funding for STEM (Science, Technology, Engineering and Mathematics) education in schools. In addition, key education policy documents highlight an expectation that teachers will be skilled at using technology and integrating it into their teaching. Standards 2.6 and 4.5 of the *Australian Professional Standards for Teachers* (AITSL, 2016) requires teachers to implement effective ICT teaching strategies in the classroom and to support students' learning with and through ICT. ICT is also included as a 'general capability' to be taught within the *Australian Curriculum.* ICT-enhanced teaching and learning is, therefore, an identifiable priority within the Australian education policy.

Yet this study has pointed to difficulties for teachers and schools in achieving the requirements set out in these policy documents. A key focus within this research pertained to identifying teachers' technological, pedagogical and content knowledge (TPACK) for teaching. Specifically, this study examined teachers' TPACK for teaching geography with GST. However, the quantitative analysis of survey results and the early adopters' reflections on their colleagues' capacity to use technology in teaching provide scope to suggest that some teachers may need support to develop further knowledge about how to implement technology into their discipline-specific teaching. As one early adopter commented:

> I think teachers are good at doing certain things within the limitations of the syllabus but when you throw in something that they're not familiar with, like GIS, and they haven't been taught what it is, it gets neglected. Regardless of how good the syllabus is, if the teacher hasn't had professional learning or doesn't look at that and go "well, gee, I need to know about that", then it just gets neglected (John, p. 18, 432-442).

The findings of this study, therefore, contribute to arguments for increased professional learning for teachers about the value of ICT in teaching and how to embed ICT within discipline-specific teaching contexts (Callaghan, Long, van Es, Reich & Rutherford, 2018; Jimoyiannis, 2010). In this study, teacher-led professional learning was suggested as a possible way of improving teachers' knowledge for teaching with technology. While this accords with some evaluative research on the

TeachMeet peer-led professional learning format adopted by two of the teachers who participated in this study (Bennett, 2012; Kuhn, Barker, Birkwood, Carty & Tumelty, 2011; Walsh, Bradshaw & Twining, 2011), further research is required to evaluate the effectiveness of this form of professional learning for discipline-specific technology-related teaching strategies, such as for geography teachers wanting to implement GST in their teaching.

In exploring teachers' working contexts, their knowledge and their experiences of teaching with GST, this study has also drawn attention to the difficulties associated with educating pre-service teachers about technology within initial teacher education (ITE) courses. None of the teachers in this study reported having learned about geospatial technologies during their ITE. This is unsurprising since many of the participating teachers completed their ITE at a time when GIS was predominantly used by technicians and before the advent of accessible web-based platforms like Google Earth or Google Maps. Indeed, while GST applications have become increasingly accessible to non-geographers, research suggests that GST are still under-utilised and under-taught in Australian ITE courses (Harte, 2017). The inclusion of these technologies in the *Australian Curriculum: Geography* appears to have also preceded the uptake of these technologies by teacher educators. Subsequently, pre-service teachers may have few opportunities to learn about GST before being expected to make use of them in their teaching once they have graduated. This disjuncture between learnings about technology in ITE and the expectations of teachers when teaching in the classroom is not limited to GST. In an age of rapid technological advances and continuing fluidity of curriculum requirements (a review of the *Australian Curriculum* is again scheduled for 2020), this study of GST in geography education has drawn attention tangentially to challenges for ITE in preparing pre-service teachers for ICT-enhanced teaching. This problem is particularly troublesome with respect to technologies that may not currently exist but that could end up becoming central to future discipline-specific curriculum requirements. Further research focused on ways of preparing pre-service teachers to use technology in teaching continues to be warranted.

This study has prompted reflection upon the broader strategic implications about how and why GST matters and might affect the thinking of policy-makers, education leaders and teacher educators. Nevertheless, the more targeted implications of this study are worth reasserting, too. This study about the adoption and use of GST by Australian secondary geography teachers has consistently argued that the use of geospatial technologies in geography education should be allowed to flourish in schools. These technologies enable complex, higher-order geographical thinking; the kind of geographical thinking which will be critical in equipping young people with the knowledge and skills needed to face the pressing social, economic and environmental problems of today’s world. It is through effective geography education, including providing opportunities for students to use a key geographical tool (GST) to manage twenty-first century geographical challenges, that teachers have the capacity to develop and nurture the knowledge, values and capacities of tomorrow’s leaders. By harnessing the opportunities presented by GST, teachers can introduce students to the powerful geography knowledge needed to address these problems.

References

Abbitt, J. T. (2011). An investigation of the relationship between self-efficacy beliefs about technology integration and technological pedagogical content knowledge (TPACK) among preservice teachers. *Journal of Digital Learning in Teacher Education*, *27*(4), 134-143.

ACIL Tasmania. (2013). *Surveying and geospatial workforce modelling: Potential skills gap for Queensland in particular with estimates extrapolated for Australia*. Retrieved from http://www.acilallen.com.au/cms_files/ACIL_QueenslandSurveyingGeospatial_2013.pdf

Agyei, D. D., & Voogt, J. M. (2011). Exploring the potential of the will, skill, tool model in Ghana: Predicting prospective and practicing teachers' use of technology. *Computers & Education*, *56*(1), 91-100.

Akinyemi, F. O. (2016). Technology use in Rwandan secondary schools: An assessment of teachers' attitudes towards geographic information systems (GIS). *International Research in Geographical and Environmental Education*, *25*(1), 20-35.

Aladağ, E. (2010). The effects of GIS on students' academic achievement and motivation in seventh-grade social studies lessons in Turkey. *International Research in Geographical and Environmental Education*, *19*(1), 11-23.

Alam, S. (2017). A note on the quality of geography textbooks for secondary students in India. *The Geographer, 64*(1), 88-97.

Albion, P., Jamieson-Proctor, R., & Finger, G. (2010). Auditing the TPACK confidence of Australian pre-service teachers: The TPACK confidence survey (TCS). In *Society for Information Technology & Teacher Education International Conference* (pp. 3772-3779). Association for the Advancement of Computing in Education (AACE).

Albion, P. R., Tondeur, J., Forkosh-Baruch, A., & Peeraer, J. (2015). Teachers' professional development for ICT integration: Towards a reciprocal relationship between research and practice. *Education and Information Technologies*, *20*(4), 655-673.

Alibrandi, M. (1998). GIS as a tool in interdisciplinary environmental studies: Student, teacher, and community perspectives. *Meridian, 2*, 1-10.

Anderson, L. W., Krathwohl, D. R., Airasian, P., Cruikshank, K., Mayer, R., Pintrich, P., ... & Wittrock, M. (2001). *A taxonomy for learning, teaching and assessing: A revision of Bloom's taxonomy*. New York. Longman Publishing.

Angeli, C., & Valanides, N. (2009). Epistemological and methodological issues for the conceptualization, development, and assessment of ICT–TPCK: Advances in technological pedagogical content knowledge (TPCK). *Computers & education*, *52*(1), 154-168.

Archambault, L. M., & Barnett, J. H. (2010). Revisiting technological pedagogical content knowledge: Exploring the TPACK framework. *Computers & Education*, *55*(4), 1656-1662.

Artvinli, E. (2010). The contribution of geographic information systems (GIS) to geography education and secondary school students' attitudes related to GIS. *Educational Sciences: Theory and Practice*, *10*(3), 1277-1292.

ASCD. (2016). *Digital content goes to school: Trends in K-12 classroom e-learning.* Retrieved from http://www.ascd.org/ASCD/pdf/siteASCD/misc/DigitalContentTrendsReport.pdf

Audet, R. H., & Paris, J. (1997). GIS implementation model for schools: Assessing the critical concerns. *Journal of Geography*, *96*(6), 293-300.

Australian Bureau of Statistics. (2011). *Schools, Australia, 2010*. Retrieved from http://www.abs.gov.au/ausstats/abs@.nsf/lookup/4221.0Main+Features62010?OpenDocument

Australian Curriculum, Assessment and Reporting Authority [ACARA]. (2014). *State and territory implementation of the foundation to year 10 Australian Curriculum*. Retrieved from http://docs.acara.edu.au/resources/State_and_Territory_F-10_Australian_Curriculum_Implementation_Timelines_July_2014_v2.pdf

Australian Curriculum, Assessment and Reporting Authority [ACARA]. (2015). *Australian Curriculum: Digital Technologies (F-10).* Retrieved from https://www.australiancurriculum.edu.au/f-10-curriculum/technologies/digital-technologies/

Australian Curriculum, Assessment and Reporting Authority [ACARA]. (2015). *Monitoring the effectiveness of the foundation – year 10 Australian Curriculum*. Retrieved from http://docs.acara.edu.au/resources/Monitoring_Report_2015.pdf

Australian Curriculum, Assessment and Reporting Authority [ACARA]. (2016). *F-10 curriculum: Humanities and social science – geography*. Retrieved from https://www.australiancurriculum.edu.au/f-10-curriculum/humanities-and-social-sciences/geography/

Australian Curriculum, Assessment and Reporting Authority [ACARA]. (2016b). *My School*. Retrieved from https://www.myschool.edu.au/

Australian Curriculum, Assessment and Reporting Authority [ACARA]. (2016c). *F-10 curriculum: Structure*. Retrieved from https://www.australiancurriculum.edu.au/f-10-curriculum/structure/

Australian Institute for Teaching and School Leadership [AITSL]. (2013). *Initial teacher education: Data report 2013*. Retrieved from https://www.aitsl.edu.au/docs/default-source/default-document-library/initial-teacher-education-data_report-2013.pdf?sfvrsn=f3beec3c_0

Australian Institute for Teaching and School Leadership [AITSL]. (2016). *Australian professional standards for teaching*. Retrieved from https://www.aitsl.edu.au/teach/standards

Australian Geography Teachers Association [AGTA]. (2007). Australians need geography. *Geographical Education, 20*, 9-14.

Babbie, E. R. (2014). *The basics of social research*. Boston, MA: Cengage Learning.

Baker, T. & Langran, E. (2016). Reflections on editing the special CITE Issue - Geospatial technologies in teacher education. In G. Chamblee & L. Langub (Eds.), *Proceedings of Society for Information Technology & Teacher Education International Conference 2016* (pp. 1631-1635). Chesapeake, VA: Association for the Advancement of Computing in Education (AACE).

Baker, T. R. (2015). WebGIS in education. In O. Muñiz Solari, A. Demirci & J. A. van der Schee. (Eds.), *Geospatial technologies and geography education in a changing world* (pp. 105-115). Tokyo: Springer Japan.

Baker, T. R. (2005). Internet-based GIS mapping in support of K-12 education. *The Professional Geographer*, *57*(1), 44-50.

Baker, T. R., & Bednarz, S. W. (2003). Lessons learned from reviewing research in GIS education. *Journal of Geography*, *102*(6), 231-233.

Baker, T. R., Battersby, S., Bednarz, S. W., Bodzin, A. M., Kolvoord, B., Moore, S., ... & Uttal, D. (2015). A research agenda for geospatial technologies and learning. *Journal of Geography*, *114*(3), 118-130.

Baker, T. R., Palmer, A. M., & Kerski, J. J. (2009). A national survey to examine teacher professional development and implementation of desktop GIS. *Journal of Geography*, *108*(4-5), 174-185.

Baker, T. R., & Kerski, J. J. (2014). Lone trailblazers: GIS in K-12 science education. In MaKinster, J.G., N.M. Trautmann, & G.M. Barnett (Eds.), *Teaching science and investigating environmental issues with geospatial technology: Designing effective professional development for teachers* (pp. 347-372). Dordrecht, Netherlands: Springer.

Ball, S. J. (1987). *The micro-politics of the school*. London: Methuen

Bartoschek, T., Schwering, A., Li, R., Münzer, S., & Carlos, V. (2018). OriGami: A Mobile Geogame for Spatial Literacy. In *Geogames and Geoplay: Game-based approaches to the analysis of geo-information* (pp. 37-62). Cham: Springer.

Battersby, S. E., Golledge, R. G., & Marsh, M. J. (2006). Incidental learning of geospatial concepts across grade levels: Map overlay. *Journal of Geography*, *105*(4), 139-146.

Baumgarten, S. A. (1975). The innovative communicator in the diffusion process. *Journal of Marketing Research*, *12*(1), 12-18.

Bednarz, R. S., & Bednarz, S. W. (2008). The importance of spatial thinking in an uncertain world. In Sui, D. Z. (Ed.), *Geospatial technologies and homeland security* (pp. 315-330). Dordrecht, NL: Springer.

Bednarz, S. W. (2003). Nine years on: Examining implementation of the national geography standards. *Journal of Geography*, *102*(3), 99-109.

Bednarz, S. W. (2004). Geographic information systems: A tool to support geography and environmental education?. *GeoJournal*, *60*(2), 191-199.

Beeson, P. A. (2006). Uncovering the secrets behind the successful integration of GIS into the core curriculum. *International Research in Geographical and Environmental Education*, *15*(3), 274-277.

Benimmas, A., Kerski, J., & Solís, P. (2011). The impact of a geographic technologies professional development institute on Middle Eastern and North African teachers. *International Research in Geographical and Environmental Education*, *20*(1), 21-45.

Bennett, E. (2012). Teachmeets: Guerilla CPD. *Educational Developments*, *3*(4), 23-27.

Bethlehem, J. (2010). Selection bias in web surveys. *International Statistical Review, 78*(2), 161-188.

Berendsen, M. E., Hamerlinck, J. D., & Webster, G. R. (2018). Digital Story Mapping to Advance Educational Atlas Design and Enable Student Engagement. *International Journal of Geo-Information*, *7*(3), 125-147.

Bijsterbosch, E., van der Schee, J., & Kuiper, W. (2017). Meaningful learning and summative assessment in geography education: An analysis in secondary education in the Netherlands. *International Research in Geographical and Environmental Education*, *26*(1), 17-35.

Blackwell, C. K., Lauricella, A. R., & Wartella, E. (2016). The influence of TPACK contextual factors on early childhood educators' tablet computer use. *Computers & Education*, *98*, 57-69.

Bloom, B. S., Engelhart, M. D., Furst, E. J., Hill, W. H., & Krathwohl, D. R. (1956). *Taxonomy of educational objectives, handbook I: The cognitive domain*. New York, NY: David McKay Co Inc.

Bodzin, A. M., & Fu, Q. (2014). The effectiveness of the geospatial curriculum approach on urban middle-level students' climate change understandings. *Journal of Science Education and Technology*, *23*(4), 575-590.

Bodzin, A. M., Fu, Q., Kulo, V., & Peffer, T. (2014). Examining the effect of enactment of a geospatial curriculum on students' geospatial thinking and reasoning. *Journal of Science Education and Technology*, *23*(4), 562-574.

Bourke, T., & Lidstone, J. (2015). Mapping geographical knowledge and skills needed for pre-service teachers in teacher education. *SAGE Open*, *5*(1), 2158244015577668.

Bowman, B. (2015). *Teacher knowledge and geospatial technologies.* Paper presented at Conversations on Knowledge for Teaching Education Technologies: Now and in the Future Conference, Launceston. Launceston: University of Tasmania.

Boykoff, M. T. (2007). From convergence to contention: United States mass media representations of anthropogenic climate change science. *Transactions of the Institute of British Geographers, 32*(4), 477-489.

Brantley-Dias, L., & Ertmer, P. A. (2013). Goldilocks and TPACK: Is the construct ‘just right?’. *Journal of Research on Technology in Education*, *46*(2), 103-128.

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, *3*(2), 77-101.

Brennan, M. (2011). National curriculum: A political-educational tangle. Australian Journal of Education, 55(3), 259-280.

Britz, H. W., & Webb, P. (2016). The effect of an intervention using GIS-generated geo-spatial data on the promotion of spatial cognition and spatial perspective taking in grade 11 learners. *South African Geographical Journal*, *98*(1), 182-193.

Brodie, S. (2006). GIS in the classroom: A New Zealand experience. *International Research in Geographical and Environmental Education*, *15*(3), 271-273.

Bruder, P. (2014). Gadgets go to school: The benefits and risks of BYOD (bring your own device). *The Education Digest*, *80*(3), 15-18.

Buchanan, J. (2016). School micro-politics and the beginning teacher: An Australian study. *Social Educator*, *34*(2), 21-32.

Cameron, R., & Miller, P. (2007). Mixed methods research: Phoenix of the paradigm wars. In *21st Annual Australian & New Zealand Academy of Management (ANZAM) Conference*. Sydney, NSW: ANZAM.

Carleton College. (2018). *Google Earth and geoscience education.* Retrieved from https://serc.carleton.edu/NAGTWorkshops/visualize04/tool_examples/google_earth.html

Callaghan, M. N., Long, J. J., van Es, E. A., Reich, S. M., & Rutherford, T. (2018). How teachers integrate a math computer game: Professional development use, teaching practices, and student achievement. *Journal of Computer Assisted Learning*, *34*(1), 10-19.

Casinader, N. (2015). Geography and the Australian curriculum: Unfulfilled knowledges in secondary school education. *Geographical Research*, *53*(1), 95-105.

Casinader, N. (2016). Secondary geography and the Australian Curriculum–directions in school implementation: A comparative study. *International Research in Geographical and Environmental Education*, *25*(3), 258-275.

Catling, S. (2014). Pre-service primary teachers' knowledge and understanding of geography and its teaching: A review. *Review of International Geographical Education Online (RIGEO)*, *4*(3), 235-260.

Cavanagh, R. F., & Koehler, M. J. (2013). A turn toward specifying validity criteria in the measurement of technological pedagogical content knowledge (TPACK). *Journal of Research on Technology in Education*, *46*(2), 129-148.

Chai, C. S., Koh, J. H. L., Tsai, C. C., & Tan, L. L. W. (2011). Modeling primary school pre-service teachers' technological pedagogical content knowledge (TPACK) for meaningful learning with information and communication technology (ICT). *Computers & Education*, *57*(1), 1184-1193.

Chan, K. K., & Misra, S. (1990). Characteristics of the opinion leader: A new dimension. *Journal of Advertising*, *19*(3), 53-60.

Chao, T., Chen, J., Star, J. R., & Dede, C. (2016). Using digital resources for motivation and engagement in learning mathematics: Reflections from teachers and students. *Digital Experiences in Mathematics Education*, *2*(3), 253-277.

Chau, P. Y., & Hui, K. L. (1998). Identifying early adopters of new IT products: A case of Windows 95. *Information & Management*, *33*(5), 225-230.

Churchill, B. (2013). Content analysis. In Walter, M. (Ed.), *Social research methods* (pp. 254-269). Oxford, UK: Oxford University Press.

Clarke, S. (2003). Stalking the micro-politics of schools in pursuit of a realistic research agenda. *Asia Pacific Journal of Education, 23*(1), 99-107

Collins, L. (2017). The impact of paper versus digital map technology on students' spatial thinking skill acquisition. *Journal of Geography*. Advance online publication. doi.org/10.1080/00221341.2017.1374990

Collins, A., & Halverson, R. (2010). The second educational revolution: Rethinking education in the age of technology. *Journal of Computer Assisted Learning*, *26*(1), 18-27.

Compagni, A., Mele, V., & Ravasi, D. (2015). How early implementations influence later adoptions of innovation: Social positioning and skill reproduction in the diffusion of robotic surgery. *Academy of Management Journal, 58*(1), 242-278.

Conti, M., Dehghantanha, A., Franke, K., & Watson, S. (2018). Internet of Things security and forensics: Challenges and opportunities. *Future Generation Computer Systems, 78*, 544-546.

Costello, A. (2018). *Newtown High School principal says classroom ban on smartphones reduced cyberbullying.* The ABC. Retrieved from http://www.abc.net.au/news/2018-09-10/new-town-high-school-bans-mobile-phones-in-classroom/10222268

Counsell, C. (2011). Disciplinary knowledge for all, the secondary history curriculum and history teachers' achievement. *Curriculum Journal, 22,* 201–225.

Creswell, J. W. (2013). *Research design: Qualitative, quantitative, and mixed methods approaches*. Thousand Oaks, CA: Sage publications.

Creswell, J. W. (2015). *The concise introduction to mixed methods research.* Thousand Oaks, CA: Sage.

Cresswell, J., & Miller, D. (2000). Getting good qualitative data to improve. *Theory into practice, 39*(3), 124-130.

Dascombe, B. (2006). Making geographic information systems (GIS) sustainable in schools. *International Research in Geographical and Environmental Education, 15*(3), 265-267.

Das, P. (2014). Land suitability analysis for orange and pineapple: A multi criteria decision making approach using geo spatial technology. *Journal of Geographic Information System, 6*(1), 40-44.

Deloitte. (2015). *Geo-spatial technology*. Retrieved from http://government-2020.dupress.com/driver/geospatial-technology/

Demirci, A. (2009). How do teachers approach new technologies: Geography teachers' attitudes towards geographic information systems (GIS). *European Journal of Educational Studies*, *1*(1), 43-53.

Demirci, A. (2015). The effectiveness of geospatial practices in education. In O. Muñiz Solari, A. Demirci, & J. A. van der Schee. (Eds.), *Geospatial technologies and geography education in a changing world* (pp. 141-153). Tokyo: Springer Japan.

Demirci, A., Karaburun, A., & Kılar, H. (2013). Using Google Earth as an educational tool in secondary school geography lessons. *International Research in Geographical and Environmental Education*, *22*(4), 277-290.

Denzin, N. K. (1989). *Interpretive interactionism.* Newbury Park, CA: Sage.

Denzin, N. K., & Lincoln, Y. S. (1994). *Handbook of qualitative research*. Thousand Oaks, CA: Sage Publications.

Department of Education (Tasmania). (2014). *Social media policy.* Retrieved from https://documentcentre.education.tas.gov.au/Documents/Social-Media-Policy.pdf

Department of Education, Commonwealth of Australia. (2014). *Review of the Australian Curriculum: Initial Australian Government responses*. Retrieved from https://docs.education.gov.au/system/files/doc/other/initial_australian_government_response_final_0.pdf

Department of Education and Training, Commonwealth of Australia. (2015). *Support for science, technology, engineering and mathematics (STEM).* Retrieved from https://www.education.gov.au/support-science-technology-engineering-and-mathematics

Department of Education and Training (NSW). (2018). *Review into the non-educational use of mobile devices in NSW*. Retrieved from https://education.nsw.gov.au/about-us/strategies-and-reports/our-reports-and-reviews/mobile-devices-in-schools

Department of Education and Training (NSW). (2015). *Information security policy*. Retrieved from https://education.nsw.gov.au/policy-library/policies/information-security-policy de Winter, J. C. (2013). Using the Student's t-test with extremely small sample sizes. *Practical Assessment, Research & Evaluation*, *18*(10).

Dickerson, M., & Gentry, J. W. (1983). Characteristics of adopters and non-adopters of home computers. *Journal of Consumer Research*, *10*(2), 225-235.

DiCicco-Bloom, B., & Crabtree, B. F. (2006). The qualitative research interview. *Medical Education*, *40*(4), 314-321.

Diederen, P., Van Meijl, H., Wolters, A., & Bijak, K. (2003). Innovation adoption in agriculture: Innovators, early adopters and laggards. *Cahiers d'Economie et de Sociologie Rurales*, *67*, 29-50.

Doering, A., Koseoglu, S., Scharber, C., Henrickson, J., & Lanegran, D. (2014). Technology integration in K–12 geography education using TPACK as a conceptual model. *Journal of Geography*, *113*(6), 223-237.

Doering, A., Veletsianos, G., Scharber, C., & Miller, C. (2009). Using the technological, pedagogical, and content knowledge framework to design online learning environments and professional development. *Journal of Educational Computing Research*, *41*(3), 319-346.

Driscoll, D. L., Appiah-Yeboah, A., Salib, P., & Rupert, D. J. (2007). Merging qualitative and quantitative data in mixed methods research: How to and why not. *Ecological and Environmental Anthropology, 3*(1), 19-28.

Erebus International. (2008). *A study into the teaching of geography in Years 3–10.* Canberra: Department of Education Employment and Workplace Relations.

Ertmer, P. A. (1999). Addressing first-and second-order barriers to change: Strategies for technology integration. *Educational Technology Research and Development*, *47*(4), 47-61.

Esri. (2015). What is GIS? Retrieved from http://www.esri.com/what-is-gis

Fabian, K., Topping, K. J., & Barron, I. G. (2016). Mobile technology and mathematics: Effects on students' attitudes, engagement, and achievement. *Journal of Computers in Education*, *3*(1), 77-104.

Favier, T. T. (2011). *Geographic information systems in inquiry-based secondary geography education: Theory and practice* (Doctoral thesis). Retrieved from https://research.vu.nl/en/publications/geographic-information-systems-in-inquiry-based-secondary-geograp

Favier, T. T., & van der Schee, J. A. (2014). The effects of geography lessons with geospatial technologies on the development of high school students' relational thinking. *Computers & Education*, *76*, 225-236.

Fargher, M. (2018). WebGIS for geography education: Towards a geocapabilities approach. *International Journal of Geo-Information, 7*(3), 111-125.

Fleischmann, E. M., Van der Westhuizen, C. P., & Cilliers, D. (2015). Interactive-GIS-Tutor (IGIST) integration: Creating a digital space gateway within a textbook-bound South African geography class. *International Journal of Education and Development using Information and Communication Technology*, *11*(2), 23.

Frattini, F., Bianchi, M., De Massis, A., & Sikimic, U. (2014). The role of early adopters in the diffusion of new products: differences between platform and non-platform innovations. *Journal of Product Innovation Management*, *31*(3), 466-488.

Freeman, C., O'Malley, K., & Eveleigh, F. (2014). *Australian teachers and the learning environment: An analysis of teacher response to TALIS 2013*.

Australian Council of Educational Research. Retrieved from https://research.acer.edu.au/talis/2

Freeman, D. (1991). Development of an educational GIS for the national curriculum, GIS in the secondary and higher education curriculum. In *Proceedings of the AGI'91* (pp. 3.6.1-3.6.4). Birmingham, UK: ICC.

Freeman, J. (2006). Geography in the Australian Capital Territory: A mixed picture. *International Research in Geographical & Environmental Education*, *15*(2), 185-188.

Fullan, M. (2014). *Leading in a culture of change.* San Francisco, CA: John Wiley & Sons.

Gahlod, N.S., Binjola, S., Ravi, R., & Arya, V.S. (2017). Land-site suitability evaluation for tea, cardamom and rubber using geo-spatial technology in Wayanad district, Kerala. *Journal of Applied and Natural Science,* 9(3), 1440-1447.

Gavin, M., & McGrath-Champ, S. (2017). Developing authority: The impact of giving public schools power to hire staff. *Asia Pacific Journal of Human Resources*, *55*(2), 255-274.

Geographical Association. (2014). *Curriculum making explained.* Retrieved December 4, 2017, from http://www.geography.org.uk/cpdevents/curriculum/curriculummaking/curriculummakingexplained

Glazer, E., Hannafin, M. J., & Song, L. (2005). Promoting technology integration through collaborative apprenticeship. *Educational Technology Research and Development*, *53*(4), 57-67.

Gold, C. M. (2006). What is GIS and what is not?. *Transactions in GIS*, *10*(4), 505-519.

Goldstein, D. L. (2010). *Integration of geospatial technologies into K–12 curriculum: An investigation of teacher and student perceptions and student academic achievement* (Doctoral thesis). Retrieved from https://fau.digital.flvc.org/islandora/object/fau%3A2942/datastream/OBJ/download/Integration_of_geospatial_technologies_into_K-12_curriculum.pdf

Goldstein, D., & Alibrandi, M. (2013). Integrating GIS in the middle school curriculum: Impacts on diverse students' standardized test scores. *Journal of Geography*, *112*(2), 68-74.

Government Accountability Office (GAO). (2015). *K-12 education: Most eighth grade students are not proficient in geography.* Washington, DC: US General Accountability Office.

Graham, C. R. (2011). Theoretical considerations for understanding technological pedagogical content knowledge (TPACK). *Computers & Education*, *57*(3), 1953-1960.

Gravel, R. J., Mayall, H., & York, C. (2016). In-service teachers' participation in a professional development program aligned with the TPACK framework. In *Society for Information Technology & Teacher Education International Conference* (pp. 2852-2853). Savanah, GA: Association for the Advancement of Computing in Education (AACE).

Graves, N., & Murphy, B. (2000). Research into geography textbooks. In A. Kent (Ed.), *Reflective practice in geography teaching* (pp. 228– 237). London: Paul Chapman

Greene, J. C. (2007). *Mixed methods in social inquiry*. San Francisco, CA: Jossey-Bass.

Hamilton, E. R., Rosenberg, J. M., & Akcaoglu, M. (2016). The Substitution Augmentation Modification Redefinition (SAMR) model: A critical review and suggestions for its use. *TechTrends, 60*(5), 433-441.

Hammond, T. C., Bodzin, A., Anastasio, D., Holland, B., Popejoy, K., Sahagian, D., Rutzmoser, S., Carrigan, J., & Farina, W. (2018). "You know you can do this, right?": Developing the geospatial technological pedagogical content knowledge and enhancing teachers' cartographic practices with socio-environmental science investigations. *Cartography and Geographic Information Science, 45*(4), 305-318.

Hanes, L., & Stone, R. (2018). A model of heritage content to support the design and analysis of video games for history education. *Journal of Computers in Education*, 1-26. doi.org/10.1007/s40692-018-0120-2

Harper, C. L., & Snowden, M. (2017). *Environment and society: Human perspectives on environmental issues* (6th ed.). New York, NY: Routledge.

Harte, W. (2017). Preparing preservice teachers to incorporate geospatial technologies in geography teaching. *Journal of Geography, 116*(5), 226-236.

Hattie, J. (2008). *Visible learning: A synthesis of over 800 meta-analyses relating to achievement*. Abingdon, UK: Routledge.

Heckman, J. J. (2010). Selection bias and self-selection. In S. N. Durlauf, & L. E. Blume (Eds.), *Microeconometrics* (pp. 242-266). London, UK: Palgrave Macmillan.

Henry, P., & Semple, H. (2012). Integrating online GIS into the K–12 curricula: Lessons from the development of a collaborative GIS in Michigan. *Journal of Geography, 111*(1), 3-14.

Hew, K. F., & Brush, T. (2007). Integrating technology into K-12 teaching and learning: Current knowledge gaps and recommendations for future research. *Educational Technology Research and Development, 55*(3), 223-252.

Hill, R. (1998). What sample size is "enough" in internet survey research?. *Interpersonal Computing and Technology: An Electronic Journal for the 21st Century, 6*(3-4), 1-12.

Hirschman, E. C. (1980). Innovativeness, novelty seeking, and consumer creativity. *Journal of Consumer Research, 7*(3), 283-295.

Hofmann E., & Svobodová H. (2017). Case studies in geography education as a powerful way of teaching geography. In P. Karvánková, D. Popjaková, M. Vančura, & J. Mládek (Eds.*), Current Topics in Czech and Central European geography education* (pp. 115-128). Cham: Springer.

Höhnle, S., Mehren, R., & Schubert, J. C. (2015). Teachers' perspectives on teacher training for better implementation of GIS in the geography classroom. *GI Forum, 2015*, 363-372.

Höhnle, S., Schubert, J. C., & Uphues, R. (2011). Barriers to GI (S) use in schools–A comparison of international empirical results. *Learning with GI*, 124-133.

Hong, J. E. (2014). Promoting teacher education of GIS using teacher centred and teacher-friendly design. *Journal of Geography, 113*(4), 139-150.

Hong, J. E. (2015). Teaching GIS and other geospatial technologies to in-service teachers. In O. Muñiz Solari, A. Demirci, & J. A. van der Schee (Eds.), *Geospatial technologies and geography education in a changing world* (pp. 117-126). Tokyo: Springer Japan.

Hong, J. E., & Stonier, F. (2015). GIS in-service teacher training based on TPACK. *Journal of Geography*, *114*(3), 108-117.

Hopkins, D. (2000). Powerful learning, powerful teaching and powerful schools. *Journal of Educational Change*, *1*(2), 135–154.

Hopson, M. H., Simms, R. L., & Knezek, G. A. (2001). Using a technology-enriched environment to improve higher-order thinking skills. *Journal of Research on Technology in Education, 34*(2), 109-119.

Hsu, H. P., Tsai, B. W., & Chen, C. M. (2017). Teaching topographic map skills and geomorphology concepts with Google Earth in a one-computer classroom. *Journal of Geography*, *117*(1), 29-39.

Hunter, J. (2015). *Technology integration and high possibility classrooms: Building from TPACK*. New York, NY: Routledge.

Hutchinson, N. (2006). Geography in Australian schools: A view from the AGTA chair. *International Research in Geographical & Environmental Education*, *15*(2), 193-198.

Ibrahim, T. (2005). Global citizenship education: Mainstreaming the curriculum?. *Cambridge Journal of Education*, *35*(2), 177-194.

International Geographical Union Commission on Geographical Education. (2016). *2016 International charter on geographical education.* Retrieved from http://www.cnfg.fr/wp-content/uploads/2017/12/Charter_2016-IGU-CGE_May_9.pdf

Jacobsen, M. (1997). *Bridging the gap between early adopters' and mainstream faculty's use of instructional technology*. Retrieved from http://www.eric.ed.gov/contentdelivery/servlet/ERICServlet?accno=ED423785

Jadallah, M., Hund, A. M., Thayn, J., Studebaker, J. G., Roman, Z. J., & Kirby, E. (2017). Integrating geospatial technologies in fifth-grade curriculum: Impact on spatial ability and map-analysis skills. *Journal of Geography*, *116*(4), 139-151.

Jarvis, C. H., Kraftl, P., & Dickie, J. (2017). (Re)connecting spatial literacy with children's geographies: GPS, Google Earth and children's everyday lives. *Geoforum*, *81*, 22-31.

Jimoyiannis, A. (2010). Designing and implementing an integrated technological pedagogical science knowledge framework for science teachers' professional development. *Computers & Education*, *55*(3), 1259-1269.

Jo, I. (2018). Spatial thinking in secondary geography: A summary of research findings and recommendations for future research. *Boletim Paulista de Geografia*, *99*, 200-212.

Jo, I., & Bednarz, S. (2009). Evaluating geography textbooks from a spatial perspective: Using concepts of space, tools of representation, and cognitive processes to evaluate spatiality. *Journal of Geography, 108*(1), 70-80.

Jones, A. T., & De Vries, M. J. (Eds.). (2009). *International handbook of research and development in technology education*. Boston, MA: Sense Publishing.

Kale, U., & Goh, D. (2014). Teaching style, ICT experience and teachers' attitudes toward teaching with Web 2.0. *Education and Information Technologies*, *19*(1), 41-60.

Kay, R., Benzimra, D., & Li, J. (2017). Exploring factors that influence technology-based distractions in bring your own device classrooms. *Journal of Educational Computing Research*, *55*(7), 974-995.

Kerski, J. J. (2000) *The implementation and effectiveness of geographic information systems technology and methods in secondary education* (unpublished doctoral dissertation). University of Colorado, Boulder.

Kerski, J. J. (2001). A national assessment of GIS in American high schools. *International Research in Geographical and Environmental Education*, *10*(1), 72-84.

Kerski, J. J. (2003). The implementation and effectiveness of geographic information systems technology and methods in secondary education. *Journal of Geography*, *102*(3), 128-137.

Kidman, G., & Palmer, G. (2006). GIS: The technology is there but the teaching is yet to catch up. *International Research in Geographical and Environmental Education*, *15*(3), 289-296.

Kinniburgh, J. C. (2008). An investigation of the impediments to using geographical information systems to enhance teaching and learning in mandatory stage 5 geography in New South Wales. *Geographical Education*, *21*, 20.

Koehler, M. J., Shin, T. S., & Mishra, P. (2012). How do we measure TPACK? Let me count the ways. In R. N. Ronau, C. R. Rakes, & M. L. Niess (Eds.), *Educational technology, teacher knowledge, and classroom impact: A research handbook on frameworks and approaches* (pp. 16-31). Hershey, PA: IGI Global

Koehler, M., & Mishra, P. (2009). What is technological pedagogical content knowledge (TPACK)?. *Contemporary Issues in Technology and Teacher Education, 9*(1), 60-70.

Koh, J. H. L., Chai, C. S., & Lim, W. Y. (2017). Teacher professional development for TPACK-21CL: Effects on teacher ICT integration and student outcomes. *Journal of Educational Computing Research*, *55*(2), 172-196.

Kotlar, J., De Massis, A., Frattini, F., Bianchi, M., & Fang, H. (2013). Technology acquisition in family and nonfamily firms: A longitudinal analysis of Spanish manufacturing firms. *Journal of Product Innovation Management, 30*(6), 1073-1088.

Kriewaldt, J., & Mulcahy, D. (2010). Professional standards for teaching school geography. *Education*, 8(20). Retrieved from http://www.curriculum.edu.au/leader/professional_standards_for_teaching_school_geograp,31904.html?issueID=12165

Kuhn, I., Barker, C., Birkwood, K., Carty, C., & Tumelty, N. (2011). *TeachMeet - librarians learning from each other.* Retrieved from http://www.dspace.cam.ac.uk/handle/1810/237027

Kulo, V. A., & Bodzin, A. M. (2011). Integrating geospatial technologies in an energy unit. *Journal of Geography*, *110*(6), 239-251.

Lagmay, A. M. F. A., Racoma, B. A., Aracan, K. A., Alconis-Ayco, J., & Saddi, I. L. (2017). Disseminating near-real-time hazards information and flood maps in the Philippines through Web-GIS. *Journal of Environmental Sciences*, *59*, 13-23.

Lai, J-S., Tsai, F., & Chiang, S-H. (2016). Integrating geo-spatial data for regional landslide susceptibility modelling in consideration of run-out signature. *The*

International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, XLI-B8, 89-93.

Lam, C. C., Lai, E., & Wong, J. (2009). Implementation of geographic information system (GIS) in secondary geography curriculum in Hong Kong: Current situations and future directions. *International Research in Geographical and Environmental Education*, *18*(1), 57-74.

Lambert, D., & Balderstone, D. (2010). *Learning to teach geography in the secondary school* (2nd ed.). Oxon, UK: Routledge.

Lambert, D., Solem, M., & Tani, S. (2015). Achieving human potential through geography education: A capabilities approach to curriculum making in schools. *Annals of the Association of American Geographers*, *105*(4), 723-735.

Lambert, D. [David Lambert]. (2017, October 5). *Geocapabilities teachers as curriculum leaders David Lambert* [video file]. Retrieved from https://www.youtube.com/watch?v=BpLz57HhACw&list=PLL-kMuJWZeDs9OtLuP79xGWimFFiURQyD

Lane, R. (2011). Exploring the content knowledge of experienced geography teachers. *Geographical Education*, *24,* 51.

Lavarakas, P. J. (2008). *Social desirability.* Retrieved from http://methods.sagepub.com/reference/encyclopedia-of-survey-research-methods/n537.xml

Lawal, D. (2014). Flood susceptibility modeling: A geo-spatial technology multi-criteria decision analysis approach. *Research Journal of Applied Sciences, Engineering and Technology*, *7*(22), 4638-4644.

Lawrence, V. (2011). *Investigation into the spatial capability of Australia*. Ordnance Survey. Retrieved from http://virtualanz.net/wp-content/uploads/2013/06/Lawrence-Report_Final2011-10.pdf

Lee, J., & Catling, S. (2017). What do geography textbook authors in England consider when they design content and select case studies?. *International Research in Geographical and Environmental Education, 26*(4), 342-356.

Lee, S. Y. (2014). Examining the factors that influence early adopters' smartphone adoption: The case of college students. *Telematics and Informatics*, *31*(2), 308-318.

Lemberg, D., & Stoltman, J. P. (1999). Geography teaching and the new technologies: Opportunities and challenges. *Journal of Education*, *181*(3), 63-76.

Levene, H. (1960). Robust tests for equality of variance. In I. Olkin (Ed.), *Contributions to probability and statistics* (pp. 278-292). Palo Alto, CA: Stanford University Press.

Levine, D. M., & Stephan, D. F. (2010). *Even you can learn statistics: A guide for everyone who has ever been afraid of statistics.* Upper Saddle River, NJ: Pearson.

Lopez, J., Rios, R., Bao, F., & Wang, G. (2017). Evolving privacy: From sensors to the Internet of Things. *Future Generation Computer Systems, 75*, 46-57.

Lynch, J. (1992). *Education for citizenship in a multicultural society*. London, UK: Cassell.

Manjulavani, K., Supriya, V.M., Suhrallekha, M., & Harish, B. (2017). *Detection of shoreline change using geo-spatial techniques along the coast between Kanyakumari and Tuticorin.* Paper presented at 2017 IEEE International

Conference on Power, Control, Signals and Instrumentation Engineering (ICPCSI), Chennai: Institute of Electrical and Electronics Engineers.

Maude, A. M. (2014). Developing a national geography curriculum for Australia. *International Research in Geographical and Environmental Education*, *23*(1), 40-52.

Maude, A. M. (2015). What is powerful knowledge and can it be found in the Australian geography curriculum?. *Geographical Education, 28*, 18-26.

Maude, A. M. (2018). Geography and powerful knowledge: A contribution to the debate. *International Research in Geographical & Environmental Education*, *27*(2), 179-190.

McClurg, P. A., & Buss, A. (2007). Professional development: Teachers use of GIS to enhance student learning. *Journal of Geography*, *106*(2), 79-87.

McCoy, M. (2018). The race to document archaeological sites ahead of rising sea levels: Recent applications of geospatial technologies in the archaeology of Polynesia. *Sustainability*, *10*(1), 185.

McInerney, M. (2002). GIS is achievable: The 'nuts and bolts' of introducing GIS in the geography classroom. *Geographical Education, 15*, 16-25.

McInerney, M., & Shepherd, R. (2006). Geography: The South Australian experience. *International Research in Geographical & Environmental Education*, *15*(2), 176-181.

McKenzie, P., Weldon, P. R., Rowley, G., Murphy, M., & McMillan, J. (2014). *Staff in Australia's schools 2013: Main report on the survey.* Australian Council for Educational Research. Retrieved from https://research.acer.edu.au/tll_misc/20/

Meaney, M. (2006). Towards geographic information systems (GIS) implementation: A case study. *International Research in Geographical and Environmental Education*, *15*(3), 283-288.

Metoyer, S., & Bednarz, R. (2017). Spatial thinking assists geographic thinking: Evidence from a study exploring the effects of geospatial technology. *Journal of Geography*, *116*(1), 20-33.

Meyer, J. W., Butterick, J., Olkin, M., & Zack, G. (1999). GIS in the K-12 curriculum: A cautionary note. *The Professional Geographer*, *51*(4), 571-578.

Miles, M. B., & Huberman, A. M. (1994). *Qualitative data analysis: An expanded sourcebook*. Thousand Oaks, CA: Sage.

Millsaps, L. T., & Harrington Jr, J. A. (2017). A time-sensitive framework for including geographic information systems (GIS) in professional development activities for classroom teachers. *Journal of Geography*, *116*(4), 152-164.

Milson, A., & Kerski, J. (2012). Around the world with geospatial technologies. *Social Education*, *76*(2), 105-108.

Mishra, P., & Koehler, M. J. (2006). Technological pedagogical content knowledge: A framework for teacher knowledge. *Teachers College Record, 108*(6), 1017-1054.

Mitchell, J. T., Roy, G., Fritch, S., & Wood, B. (2018). GIS professional development for teachers: lessons learned from high-needs schools. *Cartography and Geographic Information Science*, *45*(4), 292-304.

Mitchell, D., & Lambert, D. (2015). Subject knowledge and teacher preparation in English secondary schools: The case of geography. *Teacher Development*, *19*(3), 365-380.

Moore, S., Haviland, D., Moore, W., & Tran, M. (2016). Preparing teachers to use GIS: The impact of a hybrid professional development program on teachers' use of GIS. *Journal of Science Education and Technology, 25*(6), 930-946.

Morgan, J., & Lambert, D. (2005). *Geography*. London: Routledge

Morse J.M., & Niehaus, L. (2009). *Mixed method design: Principles and procedures*. Walnut Creek, CA: Left Coast Press.

Morse, J. M. (2003). Principles of mixed method and multimethod research design. In A. Tashakkori & C. Teddlie (Eds.), *Handbook of mixed methods in social & behavioral research* (pp. 189-208). Thousand Oaks, CA: Sage.

Mulcahy, D., & Kriedwadt, J. (2016). *Professional standards for accomplished teaching of school geography*. Retrieved from http://www.geogstandards.edu.au/

Muñiz Solari, O., Demirci, A., van der Schee, J. (2015). Geospatial technology in geography education. In O. Muñiz Solari, A. Demirci, & J. A. van der Schee (Eds.), *Geospatial technologies and geography education in a changing world* (pp. 1-10). Tokyo: Springer Japan.

Myers, J. H., & Robertson, T. S. (1972). Dimensions of opinion leadership. *Journal of Marketing Research, 9*(1), 41-46.

National Coordination Office for Space-Based Positioning, Navigation and Timing. (2015). *Constellation arrangement*. Retrieved from https://www.gps.gov/systems/gps/space/

National Oceanic and Atmospheric Association. (2014). *Remote sensing*. Retrieved from https://oceanservice.noaa.gov/geodesy/remote-sensing/

Nielsen, C. P., Oberle, A., & Sugumaran, R. (2011). Implementing a high school level geospatial technologies and spatial thinking course. *Journal of Geography, 110*(2), 60-69.

New South Wales Department of Education. (2013). *Gender analysis of school teachers*. Retrieved from http://www.dec.nsw.gov.au/documents/15060385/15385042/gender-analysis-school-teacher.pdf

Nugent, G., Barker, B., Grandgenett, N., & Adamchuk, V. I. (2010). Impact of robotics and geospatial technology interventions on youth STEM learning and attitudes. *Journal of Research on Technology in Education*, *42*(4), 391-408.

O'Dea. E. (2002). *Integrating geographic information systems and community mapping into secondary science education: A web GIS approach* (unpublished Master's dissertation). Oregon State University, Corvallis.

Olausson, U. (2011). "We're the ones to blame": Citizens' representations of climate change and the role of the media. *Environmental Communication, 5*(3), 281-299.

O'Leary, Z. (2017). *The essential guide to doing your research project*. Thousand Oaks, CA: Sage.

Palladino, S., & Goodchild, M. F. (1993). A place for GIS in the secondary schools? Lessons from the NCGIA secondary education project. *Geo Info Systems*, *3*(4), 45-49.

Palys, T. (2008). Purposive sampling. In L. M. Given (Ed.) *The Sage encyclopedia of qualitative research methods* (pp. 697-8) Los Angeles, CA: Sage.

Papastergiou, M. (2009). Digital game-based learning in high school computer science education: Impact on educational effectiveness and student motivation. *Computers & Education*, *52*(1), 1-12.

Patterson, T. C. (2007). Google Earth as a (not just) geography education tool. *Journal of Geography*, *106*(4), 145-152.

Pawson, E., Fournier, E., Haigh, M., Muniz, O., Trafford, J., & Vajoczki, S. (2006). Problem-based learning in geography: Towards a critical assessment of its purposes, benefits and risks, *Journal of Geography in Higher Education*, *30*(1), 103-116.

Pearson, L. C., & Moomaw, W. (2005). The relationship between teacher autonomy and stress, work satisfaction, empowerment, and professionalism. *Educational research quarterly*, *29*(1), 38-54.

Peralta, H., & Costata, F. A. (2007). Teachers' competence and confidence regarding the use of ICT. *Sísifo-Educational Sciences Journal*, *3*, 75-84.

Perkins, N., Hazelton, E., Erickson, J., & Allan, W. (2010). Place-based education and geographic information systems: Enhancing the spatial awareness of middle school students in Maine. *Journal of Geography*, *109*(5), 213-218.

Phakiti, A. (2018). Assessing Higher- Order Thinking Skills in Language Learning. *The TESOL Encyclopedia of English Language Teaching*, 1-7.

Phillips, D. L., & Segal, B. E. (1969). Sexual status and psychiatric symptoms. *American Sociological Review*, *34*(1), 58-72.

Phillips, M., Koehler, M., Rosenberg, J., & Zunica, B. (2017). Unpacking TPACK: Reconsidering knowledge and context in teacher practice. In *Society for Information Technology & Teacher Education International Conference* (pp.

2422-2429). Austin, TX: Association for the Advancement of Computing in Education (AACE).

Plano Clark, V. L., & Creswell, J. W. (2008). *The mixed methods reader.* Thousand Oaks, CA: Sage.

Porras-Hernández, L. H., & Salinas-Amescua, B. (2013). Strengthening TPACK: A broader notion of context and the use of teacher's narratives to reveal knowledge construction. *Journal of Educational Computing Research*, *48*(2), 223-244.

Prabhu, K., & Sivakumar, R. (2018). Groundwater quality mapping of Nandiaru Subbasin, Tamilnadu, India by using geo spatial technology. *Rasayan Journal of Chemistry*, *11*(2), 735-742.

Puentedura, R. (2010). *SAMR and TPCK: Intro to advanced practice*. Retrieved from http://hippasus.com/resources/sweden2010/SAMR_TPCK_IntroToAdvancedPractice.pdf

Radmehr, F., & Drake, M. (2018). An assessment-based model for exploring the solving of mathematical problems: Utilizing revised bloom’s taxonomy and facets of metacognition. *Studies in Educational Evaluation*, *59*, 41-51.

Ram, S., & Jung, H. S. (1994). Innovativeness in product usage: A comparison of early adopters and early majority. *Psychology & Marketing*, *11*(1), 57-67.

Rhiel, G. S., & Chaffin, W. W. (1996). An investigation of the large-sample/sample-sample approach to one-sample test for a mean (sigma unknown). *Journal of Statistics Education*, *4*(3). doi: 10.1080/10691898.1996.11910515

Richardson, D. (2004). Foreward. In S. D., Brunn, S. L. Cutter, & J. W. Harrington, Jr. (Eds.), *Geography and technology* (pp. XI-XII). Dordrecht, NL: Kluwer Academic.

Robertson, M., & Doyle, D. (2006). Geographical education in Tasmania: A fragile future?. *International Research in Geographical & Environmental Education*, *15*(2), 182-184.

Rød, J. K., Larsen, W., & Nilsen, E. (2010). Learning geography with GIS: Integrating GIS into upper secondary school geography curricula. *Norsk Geografisk Tidsskrift–Norwegian Journal of Geography*, *64*(1), 21-35.

Rogers, E. M. (2003). *Diffusion of innovations*. 5th ed. Free Press, NY.

Rosenberg, J. M., & Koehler, M. J. (2015). Context and technological pedagogical content knowledge (TPACK): A systematic review. *Journal of Research on Technology in Education*, *47*(3), 186-210.

Ross, C. E., & Mirowsky, J. (1984). Socially-desirable response and acquiescence in a cross-cultural survey of mental health. *Journal of Health and Social Behavior*, *25*(2), 189-197.

Rubio, C., Rubio, M. C., & Abraham, E. (2018). Poverty assessment in degraded rural drylands in the Monte Desert, Argentina: An evaluation using GIS and multi-criteria decision analysis. *Social Indicators Research*, *137*(2), 579-603.

Russell, M., O'Dwyer, L. M., Bebell, D., & Tao, W. (2007). How teachers' uses of technology vary by tenure and longevity. *Journal of Educational Computing Research*, *37*(4), 393-417.

Ruxton, G. D. (2006). The unequal variance t-test is an underused alternative to Student's t-test and the Mann–Whitney U test. *Behavioral Ecology*, *17*(4), 688-690.

Rynne, E., & Lambert, D. (1997). The continuing mismatch between students' undergraduate experiences and the teaching demands of the geography classroom: Experience of pre-service secondary geography teachers. *Journal of Geography in Higher Education, 21*(1), 65-77.

Sahara, E. A., Sarr, D. A., Van Kirk, R. W., & Jules, E. S. (2015). Quantifying habitat loss: Assessing tree encroachment into a serpentine savanna using dendroecology and remote sensing. *Forest Ecology and Management*, *340,* 9-21.

Sahin, I. (2006). Detailed review of Rogers' diffusion of innovations theory and educational technology-related studies based on Rogers' theory. *TOJET: The Turkish Online Journal of Educational Technology*, *5*(2), 14-23.

Sahin, I. (2011). Development of survey of technological pedagogical and content knowledge (TPACK). *TOJET: The Turkish Online Journal of Educational Technology, 10*(1). 97-105.

Sallis, J. F., & Saelens, B. E. (2000). Assessment of physical activity by self-report: status, limitations, and future directions. *Research quarterly for exercise and sport*, *71*(2), 1-14.

Santos, I. M., & Bocheco, O. (2016). Exploring BYOD usage in the classroom and policies. *International Journal of Information and Communication Technology Education (IJICTE)*, *12*(4), 51-61.

Saxena, A., & Jat, M. K. (2017). *Integration of geo-spatial technologies and CA for urban growth assessment and prediction.* Paper presented at the Joint Urban Remote Sensing Event (JURSE). Dubai: Institute of Electrical and Electronics Engineers.

Schmidt, D. A., Baran, E., Thompson, A. D., Mishra, P., Koehler, M. J., & Shin, T. S. (2009). Technological pedagogical content knowledge (TPACK): The development and validation of an assessment instrument for preservice teachers. *Journal of Research on Technology in Education*, *42*(2), 123-149.

Schubert, J. C., & Uphues, R. (2009). Learning with geoinformation in German schools: Systematic integration with a GIS competency model. *International Research in Geographical and Environmental Education*, *18*(4), 275-286.

Schulz, R., Isabwe, G. M., & Reichert, F. (2015). Investigating teachers motivation to use ICT tools in higher education. In *Internet Technologies and Applications (ITA)* (pp. 62-67), Wrexham, UK: IEEE

Schultz, R. B., Kerski, J. J., & Patterson, T. C. (2008). The use of virtual globes as a spatial teaching tool with suggestions for metadata standards. *Journal of Geography*, *107*(1), 27-34.

Seddon, G. M. (1978). The properties of Bloom's taxonomy of educational objectives for the cognitive domain. *Review of Educational Research*, *48*(2), 303-323.

Seddon, T. (2001). National curriculum in Australia? A matter of politics, powerful knowledge and the regulation of learning. *Pedagogy Culture and Society*, *9*(3), 307-331.

Sekaran, U. (2003) *Research methods for business: A skill-building approach.* New York: John Wiley & Sons.

Short, M. E., Goetzel, R. Z., Pei, X., Tabrizi, M. J., Ozminkowski, R. J., Gibson, T. B., ... & Wilson, M. G. (2009). How accurate are self-reports? An analysis of self-reported healthcare utilization and absence when compared to administrative data. *Journal of occupational and environmental medicine/American College of Occupational and Environmental Medicine*, *51*(7), 786.

Shulman, L. S. (1986). Those who understand: Knowledge growth in teaching. *Educational Researcher*, *15*(2), 4-14.

Singh, S. S. B., Rathakrishnan, B., Sharif, S., Talin, R., & Eboy, O. V. (2016). The effects of geography information system (GIS) based teaching on underachieving students' mastery goal and achievement. *TOJET: The Turkish Online Journal of Educational Technology*, *15*(4), 119-134.

Smerdon, R. (2006). Geography: The Queensland experience. *International Research in Geographical & Environmental Education*, *15*(2), 166-170.

Smith, M.L. (1987). Publishing qualitative research. *American Educational Research Journal*, *24*(2), 173–83.

Solem, M., Lambert, D., & Tani, S. (2013). Geocapabilities: Toward an international framework for researching the purposes and values of geography education. *Review of International Geographical Education Online*, *3*(3), 214-299.

South Australia Department of Education and Children's Services. (2004). R-10 society and environment teaching resource. Retrieved from http://www.sacsa.sa.edu.au/ATT/%7BF51C47E3-B6F3-4765-83C3-0E27FF5DD952%7D/R-10_Society&Environment.pdf

Stinson, M. T. (2007). *The shifting sands of curriculum development: A case study of the development of the Years 1 to 10 – the arts curriculum for Queensland schools* (doctoral thesis). Griffith University, Brisbane.

Stoltman, J., Lidstone, J., & Kidman, G. (2015). Powerful knowledge in geography: IRGEE editors interview Professor David Lambert, London Institute of Education, October 2014. *International Research in Geographical and Environmental Education*, *24*(1), 1-5.

Sui, D. Z. (1995). A pedagogic framework to link GIS to the intellectual core of geography. *Journal of Geography*, *94*(6), 578-591.

Swallow, M. J., & Olofson, M. W. (2017). Contextual understandings in the TPACK framework. *Journal of Research on Technology in Education*, *49*(3-4), 228-244.

Tambyah, M. M. (2009). “I am a secondary teacher and I teach history and SOSE”: Negotiating pre-service teacher identities in times of curriculum change. *Social Educator*, *27*(2), 13-20.

Tan G.C.I., & Chen, Q.F.J. (2015). An assessment of the use of GIS in teaching. In O. Muñiz Solari, A. Demirci A, J. A. van der Schee (Eds.), *Geospatial technologies and geography education in a changing world* (pp.155-167). Tokyo: Springer.

Teddlie, C., & Tashakkori, A. (2009). *Foundations of mixed methods research: Integrating quantitative and qualitative approaches in the social and behavioral sciences*. Thousand Oaks: Sage.

Teo, T. (2008). Pre-service teachers' attitudes towards computer use: A Singapore survey. *Australasian Journal of Educational Technology*, *24*(4), 413-424.

Teo, T. (2009). Modelling technology acceptance in education: A study of pre-service teachers. *Computers & Education*, *52*(2), 302-312.

Tondeur, J., van Braak, J., Ertmer, P. A., & Ottenbreit-Leftwich, A. (2017). Understanding the relationship between teachers’ pedagogical beliefs and technology use in education: A systematic review of qualitative evidence. *Educational Technology Research and Development*, *65*(3), 555-575.

Trautmann, N. M., & MaKinster, J. G. (2010). Flexibly adaptive professional development in support of teaching science with geospatial technology. *Journal of Science Teacher Education, 21*(3), 351-370.

Uniyal, S., Kaphaliya, B., Paliwal, R., & Sharma, R. K. (2017). Human overpopulation: Impact on environment. In R. P. Singh, A. Singh, & V. Srivastava (Eds.), *Environmental issues surrounding human population* (pp. 1-11). Hershey, PA: IGI Global.

van der Schee, J., Trimp, H., Békener, T., & Favier, T. (2015). Digital geography education in the twenty-first century: Needs and opportunities. In In O. Muñiz Solari, A. Demirci A, J. A. van der Schee (Eds.), *Geospatial technologies and geography education in a changing world* (pp. 11-20). Tokyo: Springer.

Venkatesh, V., Brown, S. A., & Bala, H. (2013). Bridging the qualitative-quantitative divide: Guidelines for conducting mixed methods research in information systems. *MIS Quarterly, 37*(1), 21-54.

Venkatraman, M. P. (1989). Opinion leaders, adopters, and communicative adopters: A role analysis. *Psychology & Marketing*, *6*(1), 51-68.

Volman, M., & van Eck, E. (2001). Gender equity and information technology in education: The second decade. *Review of Educational Research, 71*(4), 613-634.

Voogt, J., & Pelgrum, H. (2005). ICT and curriculum change. *Human Technology, 1*(2), 157-175.

Walsh, C. S., Bradshaw, P., & Twining, P. (2011). *e-Learning through collaborative teacher professional development in primary and secondary schools in England.* Paper presented at IADIS International Conference e-Learning 2011, Rome: International Association for the Development of the Information Society.

Walshe, N. (2017). Developing trainee teacher practice with geographical information systems (GIS). *Journal of Geography in Higher Education*, 41(4), 608-628.

Welsh, K. E., France, D., Whalley, W. B., & Park, J. R. (2012). Geotagging photographs in student fieldwork. *Journal of Geography in Higher Education*, *36*(3), 469-480.

Wrenn, A. (2010). History's secret weapon: The enquiry of a disciplined mind. *Teaching History, 138*, 32–41.

Weldon, P. R. (2016). *Out-of-field teaching in Australian secondary schools*. Australian Council for Educational Research. Retrieved from https://research.acer.edu.au/policyinsights/6/

Wheeler, P., Gordon-Brown, L., Peterson, J., & Ward, M. (2010). Geographical information systems in Victorian secondary schools: Current constraints and opportunities. *International Research in Geographical and Environmental Education*, *19*(2), 155-170.

Wiegand, P. (2001). Geographical information systems (GIS) in education. *International Research in Geographical and Environmental Education*, *10*(1), 68-71.

Weigand, P. (2004). *Cartography and geo-information sciences in the curriculum.* Paper presented at the Expanding Horizons in a Shrinking World Conference, International Geographical Union Commission on Geographical Education, Glasgow, Scotland. Retrieved from http://www.igu-cge.org/publications/

West, B. A. (2003). Student attitudes and the impact of GIS on thinking skills and motivation. *Journal of Geography*, *102*(6), 267-274.

Wouters, P., Van Nimwegen, C., Van Oostendorp, H., & Van Der Spek, E. D. (2013). A meta-analysis of the cognitive and motivational effects of serious games. *Journal of Educational Psychology, 105*(2), 249-265.

Xian, X., & Liu, Y. (2017). Understanding 'change' through spatial thinking using Google Earth in secondary geography. *Journal of Computer Assisted Learning, 33*, 65-78.

Xie, K., & Luthy, N. (2017). Textbooks in the digital world. *The Conversation*. Retrieved from https://theconversation.com/textbooks-in-the-digital-world-78299

Yap, L. Y., Ivy Tan, G. C., Zhu, X., & Wettasinghe, M. C. (2008). An assessment of the use of geographical information systems (GIS) in teaching geography in Singapore schools. *Journal of Geography, 107*(2), 52-60.

Young, M. (2008). From constructivism to realism in the sociology of the curriculum. *Review of Research in Education, 32*, 1-32.

Young, M., Lambert, D., Roberts, C., & Roberts, M. (2014). *Knowledge and the future school: Curriculum and social justice.* London: Bloomsbury.

Young, M., & Muller, J. (2015). *Curriculum and the specialization of knowledge: Studies in the sociology of education*. London: Routledge.

Zhao, Y., & Bryant, F. L. (2006). Can teacher technology integration training alone lead to high levels of technology integration? A qualitative look at teachers' technology integration after state mandated technology training. *Electronic Journal for the Integration of Technology in Education, 5*(1), 53-62.

Appendix A

Ethical Clearances

Social Science Ethics Officer
Private Bag 01 Hobart
Tasmania 7001 Australia
Tel: (03) 6226 2763
Fax: (03) 6226 7148
Katherine.Shaw@utas.edu.au

HUMAN RESEARCH ETHICS COMMITTEE (TASMANIA) NETWORK

UTAS

6 November 2014

Assoc Prof Rosemary Callingham
Faculty of Education
Locked Bag 1307

Student Researcher: Bianca Coleman

Sent via email

Dear Assoc Prof Callingham

Re: MINIMAL RISK ETHICS APPLICATION APPROVAL
Ethics Ref: **H0014549 - Teachers' Use of Geospatial Technologies in the Teaching of Secondary Geography (Years 7-12)**

We are pleased to advise that acting on a mandate from the Tasmania Social Sciences HREC, the Chair of the committee considered and approved the above project on 6 November 2014.

This approval constitutes ethical clearance by the Tasmania Social Sciences Human Research Ethics Committee. The decision and authority to commence the associated research may be dependent on factors beyond the remit of the ethics review process. For example, your research may need ethics clearance from other organisations or review by your research governance coordinator or Head of Department. It is your responsibility to find out if the approval of other bodies or authorities is required. It is recommended that the proposed research should not commence until you have satisfied these requirements.

Please note that this approval is for four years and is conditional upon receipt of an annual Progress Report. Ethics approval for this project will lapse if a Progress Report is not submitted.

The following conditions apply to this approval. Failure to abide by these conditions may result in suspension or discontinuation of approval.

1. It is the responsibility of the Chief Investigator to ensure that all investigators are aware of the terms of approval, to ensure the project is conducted as approved by the Ethics Committee, and to notify the Committee if any investigators are added to, or cease involvement with, the project.

A PARTNERSHIP PROGRAM IN CONJUNCTION WITH THE DEPARTMENT OF HEALTH AND HUMAN SERVICES

2. Complaints: If any complaints are received or ethical issues arise during the course of the project, investigators should advise the Executive Officer of the Ethics Committee on 03 6226 7479 or human.ethics@utas.edu.au.

3. Incidents or adverse effects: Investigators should notify the Ethics Committee immediately of any serious or unexpected adverse effects on participants or unforeseen events affecting the ethical acceptability of the project.

4. Amendments to Project: Modifications to the project must not proceed until approval is obtained from the Ethics Committee. Please submit an Amendment Form (available on our website) to notify the Ethics Committee of the proposed modifications.

5. Annual Report: Continued approval for this project is dependent on the submission of a Progress Report by the anniversary date of your approval. You will be sent a courtesy reminder closer to this date. **Failure to submit a Progress Report will mean that ethics approval for this project will lapse.**

6. Final Report: A Final Report and a copy of any published material arising from the project, either in full or abstract, must be provided at the end of the project.

Yours sincerely

Katherine Shaw
Executive Officer
Tasmania Social Sciences HREC

Department of Education
EDUCATIONAL PERFORMANCE SERVICES

2/73 Murray Street, Hobart
GPO Box 169, Hobart, TAS 7001 Australia

Tasmania

File: 2014 -45

20 February 2015

Ms Bianca Coleman
PhD Candidate
University of Tasmania
Locked bag 1307
Newnham TAS 7248

Dear Ms Coleman

Teachers' use of geospatial technologies in the teaching of secondary geography (Years 7 – 12.

I have been advised by the Educational Performance Research Committee that the above research study adheres to the guidelines established and that there is no objection to the study proceeding.

Please note that you have been given permission to proceed at a general level, and not at individual school level. You will still need to seek permission from the principal of the school to be involved in the study. Please provide them with the File number or a copy of this letter when approaching them for assistance.

A copy of your final report should be forwarded to Educational Performance Services, Department of Education, GPO Box 169, Hobart, 7001 at your earliest convenience and within six months of the completion of the research phase.

If you have further questions or concerns please contact Fiona Atkins on (03) 6165 5711.

Yours sincerely

Katrina Beams, Acting Director
(Educational Performance Services)

TASMANIAN
CATHOLIC
education office

8 July 2015

Ms Bianca Coleman
Faculty of Education
University of Tasmania
Locked Bag 1307
Launceston TAS 7250

Dear Ms Coleman

I am replying to your application requesting approval to contact Catholic secondary schools in Tasmania to conduct the research project *Teachers' Use of Geospatial Technologies in the Teaching of Secondary Geography (Years 7-12).*

Thank you for the information you have provided detailing the research project. I am happy to grant in principle permission for this research to be conducted through contact with our schools.

Please note however, that it is up to the individual school to determine whether they wish to participate in the study.

Please do not hesitate to contact this office if you require further information.

Yours sincerely

Mr John Mula
Director

Appendix B

Geospatial Technologies for Geography Education (*GST4GEOG*) Survey

Introduction

This survey informs part of the research project *Teachers' Use of Geospatial Technologies in the Teaching of Secondary Geography (Years 7-12)* being conducted by researchers at the University of Tasmania. The purpose of the research project is to identify the types of knowledge that teachers hold regarding the pedagogical use of geospatial technologies in teaching the skills and concepts in secondary Geography. This study has been designed in response to the new Australian Curriculum and its emphasis on the use of geospatial technologies in Geography.

This survey contains a series of statements about your knowledge of teaching Geography with geospatial technologies and you will be asked to rate your knowledge on a Likert scale. The survey also involves one open-ended question about details of any previous pre-service or in-service training you have received in using geospatial technologies in teaching Geography. This survey has been adapted and revised from a previous survey instrument designed by Doering, Koseoglu, Scharberg, Henricksong and Lanegrang (2014).

Your participation in this survey presents no foreseeable risks and should take up to 15-20 minutes to complete. All responses are confidential. At the end of the survey you will be asked if you would like to register your interest in participating in the next stage of the research project. If you would like to, please provide your email address when prompted. Your email address will also remain confidential and will not be linked to your survey response in any way.

Your participation in this survey is entirely voluntary. You may withdraw at any time prior to submitting the survey and your responses will not be recorded.

This research project has been approved by the Tasmanian Social Science Human Research Ethics Committee. If you have any concerns or complaints about the conduct of this research, please contact the Executive officer of the HREC (Tasmania) Network on (03) 6226 6254 or email human.ethics@utas.edu.au. The Executive Officer is the person nominated to research complaints from research participants. Please quote ethics reference number H0014549.

By clicking on the green consent button below your consent to participate in this survey is implied. If you do not wish to participate, please click the red button and you will be automatically led out of the survey.

I consent – please take me to the survey

I do not consent

Participant Attributes

ABOUT YOU

Gender: Male ☐ Female ☐

How old are you?
<25 years ☐ 25-30 years ☐ 31-40 years ☐ 41-50 years ☐ 51-60 years ☐

> 60 years ☐

ABOUT YOUR TEACHING

Select all options applicable to the year levels you <u>currently teach</u>:

☐ Year 7 ☐ Year 9 ☐ Year 11 ☐ Year 12
☐ Year 8 ☐ Year 10 ☐ Year 11

Which year levels have you had <u>most experience</u> at teaching?

☐ Primary ☐ Year 9 ☐ Year 11
☐ Year 7 ☐ Year 10 ☐ Year 12
☐ Year 8 ☐ Year 11 ☐ Year 13/TAFE

Please indicate what sort of school you are currently teaching in:
Public ☐ Independent ☐ Catholic ☐

For how long have you been teaching Geography?
0-5 years ☐ 6-10 years ☐ 11-15 years ☐ 16-20 years ☐ >20 years ☐

Below are definitions of teacher career stage as set up AITSL. Select which career stage describes you most accurately:
☐ *Graduate standard*: I am a final year pre-service teacher who expects to be at the Graduate standard at the end of my course, or I'm in my first year of teaching.
☐ *Proficient*: I have between 1 to 5 years teaching experience.
☐ *Highly Accomplished*: I am a registered teacher with more than 5 years of experience with some level of responsibility in a school or system.
☐ *Lead*: I am a registered teacher with more than 5 years of experience AND have a position of responsibility in a school or system.

If applicable, select the states you have previously worked in as a teacher:

☐ Australian Capital Territory ☐ Queensland ☐ Western Australia
☐ New South Wales ☐ South Australia ☐ Overseas (please specify): ________________
☐ Northern Territory ☐ Tasmania
☐ Victoria

ABOUT YOUR EDUCATION

What is your highest educational level?

☐ Postgraduate degree
☐ Postgraduate Diploma/certificate
☐ Bachelor degree
☐ Advanced diploma or diploma
☐ Certificate level

When did you complete your highest level of study?
☐ Between 2011 and now
☐ Between 2001 and 2010
☐ Between 1991 and 2000
☐ Between 1981 and 1990
☐ Between 1971 and 1980
☐ Between 1961 and 1970
☐ Before 1960

What is your highest level of Geography education?
☐ Secondary School (up to and including Year 10)
☐ Senior Secondary School (Years 11-12)
☐ Advanced diploma or diploma
☐ Certificate level
☐ Undergraduate degree with minor in Geography
☐ Undergraduate degree with major in Geography
☐ Postgraduate degree

When did you complete your highest level of Geography education?
☐ Between 2011 and now
☐ Between 2001 and 2010
☐ Between 1991 and 2000
☐ Between 1981 and 1990
☐ Between 1971 and 1980
☐ Between 1961 and 1970
☐ Before 1960

In which country did you complete most of your school education?
☐ Australia
☐ New Zealand
☐ UK
☐ Other, please specify:
____

Knowledge for teaching with geospatial technologies

The following statements are designed to identify the types of knowledge you hold for teaching secondary Geography with geospatial technologies. Please select the option that best describes your knowledge. Geospatial technologies include the Global Position System (GPS), Geographic Information Systems (GIS) and remote sensing (aerial and satellite images). Geospatial technologies that can be used in teaching include Google Earth, Google Maps and Spatial Genie.					
	Strongly Disagree	**Disagree**	**Neither Agree or Disagree**	**Agree**	**Strongly Agree**
Technology Knowledge (TK)					
I know how to solve my own technical problems					
I can learn technology easily					
I keep up with important new technologies					
I frequently play around with technology					
I know about a range of geospatial technologies					
I have the technical skills I need to use geospatial technology					
Content Knowledge (CK)					
I have sufficient knowledge about Geography					
I can use an analytical way of thinking, similar to what expert Geographers do					
I have various ways and strategies of developing my understanding of Geography					
Pedagogical Knowledge (PK)					
I know how to assess student progress and achievement					
I can adapt my teaching based on what students					

currently understand or do not understand					
I can adapt my teaching style for different learners					
I can assess student learning in multiple ways					
I can use a wide range of teaching approaches					
I am familiar with common student understandings and misunderstandings					
Pedagogical Content Knowledge (PCK)					
I can select teaching approaches to guide student thinking and learning in Geography					
I can select teaching resources that guide student thinking and learning in Geography					
I know how to assess student thinking and learning in Geography					
I can plan learning opportunities for students in Geography					
Technological Content Knowledge (TCK)					
I know about geospatial technologies that I can use for understanding and doing Geography					
I know how to use geospatial technologies to achieve specific learning goals in Geography					
I know how to use a GPS capable device for understanding and doing Geography					

I know how to use Google Earth for understanding and doing Geography					
I know how to use Spatial Genie for understanding and doing Geography					
Technological Pedagogical Knowledge (TPK)					
I can use geospatial technology to engage students in their learning					
I choose geospatial technologies and teaching strategies to personalise learning for students					
I can adapt the use of geospatial technology to different teaching activities					
I think critically about how to use geospatial technologies in my teaching					
I can use geospatial technologies as a tool for assessing student learning					
I can use GPS as a teaching tool					
I can use Google Earth as a teaching tool					
I can use Spatial Genie as a teaching tool					
Technological, Pedagogical and Content Knowledge (TPACK)					
I can select and plan for combining teaching strategies, geospatial technology use and content in my Geography teaching					
I can teach lessons that combine Geography content, geospatial technologies and teaching strategies					

I can respond to problems that arise when combining Geography content, geospatial technologies and teaching strategies					
I can help my colleagues to successfully combine their teaching strategies, geospatial technology use and content in Geography					

Geospatial Technology Training

Have you previously completed any training (pre-service or in-service) that focused either wholly or partially on the use of geospatial technologies in education?

Yes ☐ No ☐

If yes, please provide details about the types of training activities, the content and the context of any training activities you have participated in. Please indicate if this training was specifically focused on geospatial technologies or if geospatial technology training was a component of a broader program.

____

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Thank you for your participation.

There are further opportunities to participate in this research. We are seeking teachers to participate in a classroom observation of teaching practice of using geospatial technologies to teach secondary Geography and an interview discussing that factors that influence teachers' use of geospatial technologies.

All participation is voluntary and you can withdraw at any time without any consequences.

Would you be willing to participate further in this research?

Classroom Observation
If you are willing to be involved in a classroom observation you will be requested to nominate one lesson of your choice during which you will be using geospatial technologies to teach secondary Geography. During the lesson, a researcher will take notes about your teaching practice and the types of knowledge that you demonstrate during your use of geospatial technologies. Notes will be recorded using an observation record which the researcher will explain to you prior to the commencement of the lesson. You will also have the opportunity to review and amend the researcher's notes.

Interview
After the lesson, a short interview of about 30 minutes will be conducted in which the researcher will ask you to reflect on the lesson. During the interview you will be asked a series of open-ended questions regarding the factors that you think contribute to or constrain your efforts to use geospatial technologies in your teaching of secondary Geography. Ideally, the interview will take place on the same day as the observation (directly after the lesson, after school etc.), or if this is not possible, as close to the observation day as practical.

If you wish to participate in the classroom observation and interview, please click on the link below. You will be directed to a website where you will be able to enter your email address for contact from the researchers.

Yes, I would like to register my interest

No, thank you

Thank you for registering your interest in the next stage of this research. Please answer the questions below to help the researchers to understand the context in which you are a teacher of Geography.

Do you currently utilise geospatial technologies in your teaching of secondary Geography (Years 7-12)?

Yes ☐ No ☐

For how long have you been teaching Geography?
0-5 years ☐ 6-10 years ☐ 11-15 years ☐ 16-20 years ☐ >20 years ☐

Please indicate what sort of school you are currently teaching in:
Public ☐ Independent ☐ Catholic ☐

Which state of Australia are you currently teaching in:

☐ Australian Capital Territory
☐ New South Wales
☐ Northern Territory
☐ Queensland
☐ South Australia
☐ Tasmania
☐ Victoria
☐ Western Australia
☐ N/A

Please enter your email address:

Thank you for participating in this study. The researchers will be in contact shortly.

Appendix C
Interview Questions

To gain a greater understanding of the context conditions that influence early adopters' use of geospatial technologies in their geography teaching and to further address the research interviews were conducted with the eight early adopters (Sarah, Liam, Georgia, Melissa, Elizabeth, Russell, John and Eric). Consistent with the explanatory sequential mixed-methods design of this study, the schedule of interview questions were generated in response to the analysis of the *GST4GEOG* survey. As argued by Creswell (2015), "the intent of the explanatory sequential design is to begin with the quantitative strand and then conduct a second qualitative strand to explain the quantitative results" (p. 38). It is, therefore, vital to the success of the mixed-methods approach to justify the interview questions asked of participants and the relationship between these questions and the quantitative findings Justification for the schedule of interview questions is situated here in this chapter after the initial introduction of the participating early adopters as a means of further acknowledging that context conditions influence how the early adopters interpret and respond differently to interview questions.

TPACK Interview Questions

While the survey findings provided for a generalised assessment of the TPACK of early adopters of GST for geography teaching, further explanation is required to understand how teachers act on their technological, pedagogical and content knowledge in their practice. The survey determined that early adopters reported being least knowledgeable in technology knowledge (TK), technological pedagogical knowledge (TPK), technological content knowledge (TCK) and technological, pedagogical and content knowledge (TPACK) domains (Table 1)

Table 1

TK, TCK, TPK, and TPACK means and standard deviations

TPACK Domain	Mean	Standard Deviation
TK	3.65	0.80
TCK	3.83	0.85
TPK	3.52	0.83
TPACK	3.83	0.87

N= 53

To allow early adopters the opportunity to explain how they use their knowledge of technology, pedagogy, and content in teaching geography with GST, two initial interview questions (IQ) were posed:

IQ1: *What role do you see for geospatial technologies in geography education?*

IQ2: *Why would you use geospatial technologies in your teaching rather than a more traditional means of instruction (e.g. an atlas)?*

The purpose of these interview questions was to explore the early adopters' understandings of how the use of technology changes representations of geography content and the pedagogical strategies they might use for teaching that content (Mishra & Koehler, 2006; Koehler & Mishra, 2009).

During the qualitative research phase, early adopters were also asked to supply examples of how they have previously used GST for geography teaching. Some early adopters provided the researcher with a physical copy of previous lesson plans, worksheets, and de-identified student work samples which demonstrated their use of

GST in their teaching ('teaching artefacts'). These examples provided opportunities to explore how the early adopters plan and teach their GST-enhanced lessons. The following questions were therefore devised to encourage the teachers to reflect on their decisions about their use of GST and how they acted on their TPACK during their teaching:

IQ4: *Can you tell me how you went about planning these activities and why you planned them the way you did?*

IQ5: *How do you think the addition of technology to this task change or improve it?*

IQ6: *How did you help students through this task?*

Reflecting the nature of semi-structured interviews (DiCicco-Bloom & Crabtrree, 2006), these additional questions were used as prompts to guide the teachers in their discussions of their practice. For some teachers, their reflections of practice occurred during their responses to other interview questions and so the researcher did not need them to elaborate further. In other instances, these questions were explicitly asked of teachers to elicit reflections on their practice, their contexts and their decisions to use GST for teaching.

Early adopters reported being most knowledgeable about pedagogy (PK) and their ability to combine geography content and pedagogy (PCK) (Table 2).

Table 2

PK and PCK means and standard deviations

TPACK Domain	**Means**	**Standard deviations**
PK	4.36	0.46
PCK	4.30	0.57

N = 53

While the survey revealed that the early adopters reported high levels of PK and PCK, the survey did not explicitly examine how the teachers perceive of and act on their pedagogical and pedagogical content knowledge in practice. Indeed, to date, few research studies have sought to examine examples of how geography teachers' express their PCK (Lane, 2015). Accordingly, the paucity of existing research on this phenomenon provided a rationale for examining how early adopters describe their pedagogical approaches for teaching geography content. Two interview questions were devised to identify how teachers speak to and act on their understandings about the relationship between geography content and pedagogy:

IQ7: *What is the best way to teach geography?*

IQ8: *What do you think students should know, do, and understand in geography?*

Similarly, the survey revealed teachers felt quite knowledgeable about their geography content knowledge (CK). The overall mean for CK was third highest amongst the seven TPACK domains (M = 4.04, SD = 0.62). This result also required further unpacking and explanation. A recurrent argument found within the existing literature on geography education in Australia is that many geography teachers, particularly those non-geography specialists 'teaching out of area', do not have formal geography education training (Wheldon, 2016). A clear rationale existed, therefore, for uncovering how the early adopters in this study conceived of and understood geography content. The following interview provided scope for identifying geography early adopters' knowledge of geography content:

IQ9: *What do you think geography, as a discipline, is all about?*

Demographic Characteristics

Some demographic variables (namely age, length of geography teaching experience, and highest level of geography education) were found to be associated with higher self-reports within some of the TPACK domains. Older teachers reported higher mean scores for PK and PCK than younger teachers. More experienced geography teachers reported higher means for PK and PCK than less experienced teachers. Males self-reported higher means for CK, TCK, TPK and TPACK than women. Teachers with tertiary qualifications in geography reported higher CK scores than teachers with secondary school geography education levels. Two interview questions were subsequently designed to explore evidence of the relevance and utility of the demographic variables in identifying characteristics of early adopters of GST. These questions prompted early adopters to consider how their professional and personal backgrounds and attributes might differ from those of later/non-adopters of GST.

IQ10: *Can you tell me about your background (personal, professional)?*

IQ11: *What sets you apart from other teachers that have yet to or are unwilling to adopt geospatial technologies in their teaching?*

Use of GST in Teaching

When asked about their confidence for teaching with geospatial technologies commonly used for geography education, teachers reported being most confident about teaching with the Google mapping platforms, Google Earth and Google Maps (Table 3).

Table 3

Confidence for Google Earth and Google Maps means and standard deviations

Technology	Mean	Standard Deviation
Google Earth	4.20	0.87
Google Maps	4.31	0.79

n = 51

Given teachers' confidence for teaching with the Google platforms, an examination of whether teachers are using Google Earth and Google Maps in their geography teaching was warranted. To elicit reflections on how the teachers have taught with geospatial technologies in the past, the following interview question was posed:

IQ12: *Can you tell me about some examples of where and how you have used geospatial technologies for teaching geography in your classroom?*

As some of the early adopters in this study did not provide the researcher with 'teaching artefacts' (e.g. lesson plans, worksheets, de-identified student work samples) reflecting their use of GST for geography teaching, early adopters' responses to this interview question proved highly valuable for analysing how the teachers enacted their TPACK when planning and teaching geography using GST.

Influence of Context

Content analysis of early adopters' responses to the four open-ended questions revealed a range of perceived barriers and enablers to teaching with geospatial technologies within their teaching contexts. The most frequently cited barriers included cost of equipment and software (17), limited technology access (11) and limited teacher knowledge of GST (11). The most frequently cited enablers of GST teaching included technology ease of use (4) and the availability of web-based geospatial technologies (3). While the survey provided a reasonable picture of the barriers and enablers perceived to be most significant by the teachers, the limited scope for early adopters to provide written responses short responses did not allow for a deep analysis of the impact of context on their ability to develop and act on their TPACK. To gain a better understanding of the context conditions in which the teachers work and the extent to which these conditions enable and/or constrain their use of GST, the following interview questions were also asked:

IQ13: *What kinds of things influence your decisions to use geospatial technologies in your geography teaching?*

IQ14: *What things enable you to use geospatial technologies in your teaching?*

IQ15: *What things limit your ability to use geospatial technologies in your teaching?*

IQ16: *What kinds of technology access do you have in your school?*

A persistent critique of the Technological, Pedagogical and Content Knowledge (TPACK) framework is that it does not pay due diligence to the impact of student and teacher-related factors on the development and enactment of technology with technology (Porras-Hernández and Salinas-Amescua, 2013; Rosenberg & Koehler, 2015). Evidence from the survey lends weight to this critique. Early adopters regarded ‘student engagement’ as both a barrier and an enabler to their GST-enhanced geography teaching. In the open-ended responses, one teacher commented that GST “will excite/engage students to allow better learning outcomes” (anonymous response). Another teacher, however, argued that students “often get distracted and carried away with technology” (anonymous response). As the primary purpose of the questions was to examine early adopters' TPACK, there was limited scope to explore their perceptions of the student and teacher-related factors that (may) influence their GST adoption. Acknowledging the survey evidence supporting this TPACK critique, four interview questions were designed to identify and explain student and teacher-related factors influencing early adopters' use of geospatial technologies:

IQ17: *What are your perceptions around students' learning when geospatial technologies are used in your teaching?*

IQ18: *What background (geographical, technological) knowledge are students coming into your classroom with?*

IQ19: *What do you think stops other teachers from using geospatial technologies?*

IQ20: *How can we encourage other teachers to use geospatial technologies in their teaching?*

Appendix D

Sample of Interview Transcription

Liam interview 2

Liam discusses his day in which he had students doing peer support training and he talked about how good Peer Support is at his school. The interview took place at 3.45 pm – Bianca at UTAS and Liam at his school – via Skype. Skype was behaving much better this time and the conversation flowed much more freely.

2.52 – 5.21

B: So you've given me the "I've Been Everywhere, Man" task plus the animation for the El Nino task, can you tell me how you went about planning these activities and why you planned them?

L: Alright, so I'll start with I've Been Everywhere, the objective was it was going to be one of our first ICT lessons in geography. It was designed for students to do things that we knew they could do and that was watch a YouTube clip. I ran it through Google Classroom so I had the kids connect to Google Classroom and go to the first assignment which was the "I've Been Everywhere, Man" instruction document. They clicked on the link, they got taken to the video and they watched the video and they had to write down the names [of the towns mentioned on the video]. This was kind of them identifying communities, Australian communities, which is still part of the NSW Syllabus in Year 9. We haven't kicked over to the Australian Curriculum yet. Identifying a range of place names in Australia – some of which they would know, some of which they wouldn't. So they had to write down the names of the places or go and look up the lyrics on another website and print them out or write them down and then do a Google search to find these places.

The next part of the activity was to create a Google MyMap. That was less successful and I'll give you the reasons for that in a minute. We were able to assess kid's ability to listen to and identify names of Australian places. There's some spelling and literacy issues around the funny names and spellings like Coober Pedy